PROCEEDINGS

OF THE

Forty-second Annual Meeting

Indiana Academy *of* Science

VOLUME 36
1926

J. J. Davis, *Editor*

Held at Indiana State Normal School
Muncie, Indiana
December 2-4, 1926

INDIANAPOLIS:
WM. B. BURFORD, CONTRACTOR FOR STATE PRINTING AND BINDING
1927

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ORIGINAL CONSTITUTION OF THE INDIANA ACADEMY OF SCIENCE[1]

We, whose names are hereto subscribed, citizens of the State of Indiana, do hereby associate ourselves together as a corporation under the laws of said state.

The name of this association shall be: "Indiana Academy of Science."

The objects of said association are scientific research and the diffusion of knowledge concerning various departments of science.

Members of said academy shall consist of two classes, active and honorary.

The officers of said academy shall consist of a president, three vice-presidents, secretary, treasurer, and librarian, who shall perform the duties usually pertaining to their several offices, and such other duties as shall be prescribed by the by-laws of the academy.

The officers of said academy shall constitute an executive committee.

The officers shall be chosen by ballot at the annual meeting each year, and shall serve one year, or till their successors are elected.

Said Academy may adopt such constitution and by-laws as are not inconsistent with the laws of the state and the objects herein expressed.

The place of the general business of said Academy shall be Indianapolis, Marion County, Indiana, where the annual meetings shall be held. Other meetings may be held at such times and places as may be determined by the executive committee from time to time.

The Seal of such Academy shall consist of an outer circle within which are the words "Indiana Academy of Science", an interior circle containing the word "Seal" and the date "AD 1886"—an impression of which seal is hereto affixed as a part hereof.

The following signatures were attached:

J. T. Scovell, Terre Haute.
Maurice Thompson, Crawfordsville.
David S. Jordan, Bloomington.
O. P. Jenkins, Terre Haute.
E. R. Quick, Brookville.
Stanley Coulter, Terre Haute.
J. P. D. John, Greencastle.
Thos. B. Redding, New Castle.

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[1] This constitution and list (mostly autographs) of the original members of the Indiana Academy of Science in 1885 as it was verified by the treasurer Dr. O. P. Jerkins and forwarded to the Secretary Amos W. Butler Jan. 4, 1886.

In later years it was lost. Special efforts were made to find it at the 25th meeting without success. Dr. Harlow Lindley of the department of History, Earlham College, Richmond, wrote Mr. Butler December 4, 1926, and sent therewith the original list, copy of the constitution, certificate of incorporation, and Dr. Jenkins' letter and other papers which he found in an envelope in the college library. He said of this package: "I think it must have gotten here with miscellaneous papers and pamphlets which Mrs. Dennis turned over to me for the college library after Professor Dennis's death," and which he had been unable before that time to examine.

The above note was furnished by Amos W. Butler.—Editor.

Carl H. Eigenmann, Bloomington.
S. P. Stoddard, Brookville.
L. D. Waterman, Indianapolis.
D. A. Owen, Franklin.
David R. Moore, Brookville.
B. W. Evermann, Bloomington.
Chas. R. Dryer, Ft. Wayne.
Morton W. Fordice, Bloomington.
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Jerome McNeill, Bloomington.
O. P. Hay, Irvington.
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G. K. Greene, New Albany.
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C. A. Waldo, Terre Haute.
D. W. Dennis, Richmond.
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John C. Branner, Bloomington.
Amos W. Butler, Brookville.
John M. Coulter, Crawfordsville.
R. T. Brown, Indianapolis.
Fletcher M. Noe, Indianapolis.
J. O. Stillson, Indianapolis.
H. L. Osborn, Lafayette.
W. DeM. Hooper, Indianapolis.
J. P. Naylor, Bloomington.
J. B. Burris, Cloverdale.
Henry Jameson, Indianapolis.
E. E. Glover, Terre Haute.
W. H. Mushlitz, Evansville.
A. J. Phinney, Muncie.
Chas. W. Hargitt, Moore's Hill.
J. N. Hurty, Indianapolis.
A. W. Brayton, Indianapolis.
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Wm. H. Fogg, Jeffersonville.
A. B. Porter, Richmond.
T. J. McAvoy, Indianapolis.
Daniel Kirkwood, Bloomington.
Richard Owen, New Harmony.
F. M. Webster, Lafayette.
J. B. Conner, Indianapolis.
Fred'k Stein, Indianapolis.
Lillie J. Martin, Indianapolis.
G. W. Puterbaugh, Greenfield.

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Secretary, **RAY C. FRIESNER**, Butler College, Indianapolis.
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Press Secretary, **H. F. DIETZ**, State Conservation Commission, Indianapolis.
Treasurer, **C. M. SMITH**, Purdue University, Lafayette.[1]
Editor of Proceedings, **J. J. DAVIS**, Purdue University, Lafayette.

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[1] H. E. Enders acted as treasurer in the interim following Professor Smith's death.

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PAST OFFICERS OF THE INDIANA ACADEMY OF SCIENCE

YEAR	PRESIDENT	SECRETARY	PRESS SECRETARY	TREASURER	EDITOR‡
1886	Davis S. Jordan	Amos W. Butler		O. P. Jenkins	
1887	John M. Coulter	Amos W. Butler		O. P. Jenkins	
1888	*J. P. D. John	Amos W. Butler		O. P. Jenkins	
1889	*John C. Branner	Amos W. Butler		O. P. Jenkins	
1890	*T. C. Mendenhall	Amos W. Butler		O. P. Jenkins	
1891	O. P. Hay	Amos W. Butler		O. P. Jenkins	
1892	*J. L. Campbell	Amos W. Butler		C. A. Waldo	
1893	J. C. Arthur	Amos W. Butler		C. A. Waldo	
1894	W. A. Noyes	C. A. Waldo		W. P. Shannon	
1895	A. W. Butler	John S. Wright		W. P. Shannon	C. A. Waldo
1896	Stanley Coulter	John S. Wright		W. P. Shannon	C. A. Waldo
1897	*Thomas Gray	John S. Wright		W. P. Shannon	C. A. Waldo
1898	*C. A. Waldo	John S. Wright	Geo. W. Benton	J. T. Scovell	G. W. Benton
1899	C. H. Eigenmann	John S. Wright	Geo. W. Benton	J. T. Scovell	G. W. Benton
1900	*D. W. Dennis	John S. Wright	Geo. W. Benton	J. T. Scovell	G. W. Benton
1901	*M. B. Thomas	John S. Wright	Geo. W. Benton	J. T. Scovell	D. Bodine
1902	Harvey W. Wiley	John S. Wright	Geo. W. Benton	J. T. Scovell	D. Bodine
1903	W. S. Blatchley	John S. Wright	G. A. Abbott	W. A. McBeth	W. J. Karslake
1904	C. L. Mees	John S. Wright	G. A. Abbott	W. A. McBeth	D. Bodine
1905	John S. Wright	B. McMullen	G. A. Abbott	W. A. McBeth	E. G. Martin
1906	Robert Hessler	B. McMullen	Charles R. Clark	W. A. McBeth	A. L. Foley
1907	D. M. Mottier	B. McMullen	G. A. Abbott	W. A. McBeth	L. B. McMullen
1908	Glenn Culbertson	J. H. Ransom	G. A. Abbott	W. A. McBeth	H. L. Bruner
1909	A. L. Foley	J. H. Ransom	G. A. Abbott	W. A. McBeth	H. L. Bruner
1910	*P. N. Evans	Geo. W. Benton	J. W. Woodhams	W. J. Moenkhaus	L. J. Rettger
1911	C. R. Dryer	A. J. Bigney	Milo H. Stuart	W. J. Moenkhaus	L. J. Rettger
1912	L. P. Naylor	A. J. Bigney	Milo H. Stuart	W. J. Moenkhaus	C. C. Deam
1913	*Donaldson Bodine	A. J. Bigney	F. B. Wade	W. J. Moenkhaus	H. E. Barnard
1914	Severance Burrage	A. J. Bigney	F. B. Wade	W. A. Cogshall	H. E. Barnard
1915	W. A. Cogshall	A. J. Bigney	F. B. Wade	Wm. M. Blanchard	H. E. Barnard
1916	A. J. Bigney	H. E. Enders	F. B. Wade	Wm. M. Blanchard	L. F. Bennett
1917	W. J. Moenkhaus	H. E. Enders	F. B. Wade	Wm. M. Blanchard	L. F. Bennett
1918	E. B. Williamson	H. E. Enders	F. B. Wade	Wm. M. Blanchard	L. F. Bennett
†1919	E. B. Williamson	H. E. Enders	F. B. Wade	Wm. M. Blanchard	E. Payne
1920	H. L. Bruner	H. E. Enders	F. B. Wade	Wm. M. Blanchard	F. J. Breeze
1921	Howard E. Enders	Walter N. Hess	F. B. Wade	Wm. M. Blanchard	F. Payne
1922	F. M. Andrews	Walter N. Hess	F. B. Wade	Wm. M. Blanchard	J. J. Davis
1923	Charles A. Behrens	Walter N. Hess	H. F. Dietz	Wm. M. Blanchard	J. J. Davis
1924	C. C. Deam	Flora Anderson	H. F. Dietz	Wm. M. Blanchard	J. J. Davis
1925	E. R. Cumings	Flora Anderson	H. F. Dietz	Wm. M. Blanchard	J. J. Davis
1926	W. M. Blanchard	R. C. Friesner	H. F. Dietz	C. M. Smith	J. J. Davis
1927	Frank B. Wade	R. C. Friesner	H. F. Dietz	M. W. Lyon, Jr.	

*Deceased. †Officers continued—Annual meeting not held because of influenza epidemic. ‡Listed in year of Proceedings edited.

MINUTES OF THE SPRING MEETING, 1926

DUNES PARK, MICHIGAN CITY, INDIANA.

The Indiana Academy of Science met for its Spring Meeting at Michigan City, Indiana, May 20, 21, and 22, 1926. Headquarters were at the Spaulding Hotel.

Sixty-two members and guests enjoyed the wonder of this unique section of Indiana. Those present were: A. R. Addington, G. W. Albertson, Flora Anderson, H. S. Anderson, E. A. Baie, Lora Baker, Mrs. C. H. Baker, Mrs. A. Behrens, C. H. Behrens, W. M. Blanchard, Mr. and Mrs. F. J. Breeze, Mr. and Mrs. Charles Brossman, A. W. Butler, C. B. Christy, Dr. and Mrs. Stanley Coulter, H. C. Cowles, Mr. and Mrs. F. P. Cullman, E. R. Cumings, J. J. Davis, D. H. Dunham, H. E. Enders, Ethel B. Finster, R. C. Friesner, H. B. Froning, E. L. Gardner, A. L. Giordiano, Martin Goshorn, Alice Gracy, F. V. Graham, Mr. and Mrs. Laurenz Greene, H. Hansford, R. N. Harger, Cora B. Hemmel, H. Hourck, F. G. Hufford, O. L. Kelley, Emma Lieber, Richard Lieber, Mr. and Mrs. M. W. Lyon, E. G. Mahin, C. A. Malott, J. A. Nieuwland, A. L. Pierce, W. P. Rawles, W. E. Riecken, S. A. Rifenburgh, Robert Scofield, Mrs. Schickel, N. M. Shock, C. M. Smith, Charles Stoltz, H. G. Warren, Mr. and Mrs. Paul Weatherwax, Mr. and Mrs. M. L. Weems.

BUSINESS SESSION.

HOTEL SPAULDING, MAY 20, 1926.

Meeting called to order by President Blanchard at 8:00 p. m.

Upon motion by Doctor Lyon and duly passed by members of the Academy President Blanchard appointed A. W. Butler chairman and John S. Wright and Ray C. Friesner members of a committee to look after the interests of the Academy in the proposed new State Library and Museum.

President Blanchard reported that he had communicated with Senators Watson and Robinson and others concerned, voicing the protest of the Academy against the Stanchfield Grazing Bill which sought to grant certain grazing rights which, in the opinion of scientists, would cause incalculable loss to our national forests. Prof. H. C. Cowles reported that the above mentioned bill had been temporarily tabled in congressional committee.

Action similar to the above was authorized against the Yellowstone Reservoir Bill, which seeks to permit the removal of some 20 square miles from Yellowstone National Park.

The Secretary was instructed to write letters of sympathy to the widow of the late Judge Robert McBride and to the widow of the late Prof. A. H. Young, both honored and highly esteemed members of this Academy.

President Blanchard suggested that the Academy could render valuable service to the high schools of the State by admitting more of the teachers of science into its membership.

The Program Committee announced plans for the field work of the next day. Prof. H. C. Cowles then gave a most interesting and instructive talk on the flora and physiographic features of the Dunes Region. This was followed by interested and pointed remarks on the flora and fauna of the Dunes by Dr. M. W. Lyon.

Dean Stanley Coulter reported briefly on the status of the Dunes Park work by the Conservation Commission.

The meeting was adjourned to meet at 8:00 a. m. for the trips of the following day.

FRIDAY, MAY 21

Academy members and friends assembled at the Hotel Spaulding and left by automobile at 8:00 a. m. for Mineral Springs.

At a brief business session held following the steak fry at Waverly Beach, at 7:30 p. m. the following 20 new members were voted into the Academy:

Atkins, Dora, Assistant in Botany, Butler College.

Carter, Annice, Asst. in Geol. and Geog., Ball Teachers' College, Muncie.

Champion, C. C., Terre Haute.

Cooprider, J. L., Teacher of Biology, Evansville.

Cowles, Henry C., Professor of Botany, Chicago University.

Garregies, John Paul, Teacher, Brazil.

Giordiano, Dr. Alfred, Epworth Hospital, South Bend.

Gracy, Dr. Alice, Physician, South Bend.

Hufford, Gayle, Teacher of Biology, Joliet High School.

Kelly, Lowell E., Biology Student, Purdue University, Lafayette.

King, Mary E., Student of Biology, Terre Haute.

Mengenhardt, Dennis, Student, Center Point.

Michael, Curtis, Teacher, Jasonville.

Moore, John A., Asst. in Botany, Butler College, Indianapolis.

Pittman, Lenard, Teacher, Terre Haute.

Smith, Elmer A., Consulting Engineer, Secaucus, N. J.

Stanton, Joseph, Student in Chemistry, Terre Haute.

Warren, Harris, Student in Biology, Purdue University, Lafayette.

Willis, Fred, Student, Terre Haute.

Worth, Leefe, Assistant in Botany, Butler College, Indianapolis.

Meeting adjourned sine die.

RAY C. FRIESNER, Secretary.

WINTER MEETING

Program of the Forty-second Annual Meeting of THE INDIANA ACADEMY OF SCIENCE

held at

THE BALL TEACHERS' COLLEGE,
MUNCIE, INDIANA.

December 2, 3, and 4, 1926.

Thursday, December 2, 1926.

10:00 a. m. Meeting of Entomologists of Indiana.
8:00 p. m. Meeting of the Executive Committee.
Reports of Officers and Committees.

Friday, December 3, 1926.

9:30 a. m. General Session.
General Business Session.
Greetings, Pres. Benjamin J. Burris.
  In Memoriam—
    Clarence A. Waldo....................Stanley Coulter
    Robert W. McBride..................W. S. Blatchley
    C. M. Smith..............................W. H. Bair
Presentation of Papers of General Interest.
  The Status of Science Education......James F. Mackell
  *An Attempt to Develop Spelling Consciousness[1] ....Clem O. Thompson
  *Conservation of National Aquatic Resources...... ....Barton W. Evermann
  Teaching Conservation in Indiana......Sidney R. Esten
  *The Hopi Snake Dance of 1925.......Albert B. Reagan
  President's Address—The Unselfish Service of Science.... ....William M. Blanchard
12:00 Noon. Academy Luncheon.
2:00 p. m. Sectional Meetings.

BOTANY

Vaucheria aversa......................F. M. Andrews
A List of Algae of Monroe County, Indiana II. ....F. M. Andrews

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* Papers starred not published in this Proceedings.

[1] To be published in Journal of Educational Psychology.

Reversion in Trillium ....F. M. Andrews
Lycopodium complanatum.............F. M. Andrews
*Reforestation in Indiana..............Stanley Coulter
*List of the Flowering Plants, Ferns, and Fern Allies, Collected in the Dunes State Park and Vicinity[2]..................Marcus Ward Lyon, Jr.
On the Continued Growth of Certain Fern Prothallia..........................David M. Mottier
*On the Occurrence of an Endophytic Fungus in the Prothallium of Osmunda Claytoniana.......... ....David M. Mottier
Indiana Plant Diseases, 1925........Max W. Gardner
The Seeding Habits of the White Snakeroot, *Eupatorium urticaefolium* Reichard.Albert A. Hansen
Recent Indiana Weeds, 1926.........Albert A. Hansen
*The Relation of White Snakeroot, *Eupatorium urticaefolium* Reichard, to Milk Sickness....... ....Albert A. Hansen
A Botrytis Disease of *Ribes Odoratum* Wendl.... ....J. M. Van Hook
Natural Production of Seedlings within a Pumpkin ....T. G. Yuncker
Amorphophallus titanum...............T. G. Yuncker
Additional Bibliography of the Genus Cuscuta ....T. G. Yuncker
*Anomaly in the Dandelion............Flora Anderson
Survey of the Vegetation in the Vicinity of Cement Mills.................................C. L. Porter
Airplane Photography and Ecological Mapping ....Stanley A. Cain
Photomicrography as an Aid to Teaching and Research in Biology.................Edwin J. Kohl
The Effect of Fertilizer in the Control of Corn Root Rot..........................Charles T. Gregory
Fungi Growing in "Mineral Oil".......Robert Hessler

GEOGRAPHY—GEOLOGY—ARCHEOLOGY.

Note on the So-called Synthetic "Aqua Marine"... ....Frank B. Wade
Some Features of the Cincinnati Arch as shown by Geological Conditions in an Indiana Gas Field ....W. N. Logan
The Silurian Coral Reefs of Northern Indiana and their Associated Strata....................... ....E. R. Cumings and R. S. Shrock

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* Papers starred not published in this Proceedings.

[2] To be published in The Midland Naturalist.

Notes on the Present Status of Waterway Development in the United States............J. E. Switzer
Indiana's Ability to Support Higher Education; Analyzed and Compared with that of Michigan, Wisconsin, Minnesota, Iowa, Illinois, and Ohio.. ....S. S. Visher
Bell Creek—Fall Creek Valley.................. ....Annice Carter and Louise Painter
Porter's Cave and Recent Drainage Adjustment in its Vicinity.......................A. R. Addington
Notes on the Areal Geology of Miami County, Indiana............................W. E. Tharp
Fossils from the Mancos-Dakota-Tununk Formation in the Vicinity of Steamboat, Arizona........ ....Albert B. Reagan
*Narrow Upland Spurs near Bluff Mills, Montgomery County, Indiana..Fred J. Breeze and James Pugh
Proper Motion of Weisse XXIII 175....W. A. Cogshall
*Photographs of Milky Way............W. A. Cogshall

PHYSICS—CHEMISTRY—MATHEMATICS.

A New Type of Sound Amplifying Horn........ ....Arthur L. Foley
The Effect of a Dissolving Salt on the Pitch of a Vessel Partially Filled with Water...Arthur L. Foley
Toxicity of Colloidal Arsenic to Plants.....R. H. Carr
Mathematics and the Other Sciences Will E. Edington
*Some Observations on the Rotation of the Plane of Polarization of Light Passing through a Glass Rod Produced by Strains Due to Sound....... .... Rolla A. Cook
Notes on Qualitative Analysis........Ralph W. Hufferd
An Indestructible Steam-bath........Ralph W. Hufferd
An Improved Test for Acetone in Urine.......... ....R. E. Lyons and J. T. Brundage
A Study of the Available Methods for the Determination of Selenium in Organic Compounds.. ....W. E. Brandt and R. E. Lyons
A Qualitative Study of the Catalytic Hydrogenation of the Oxides of Carbon.................. ....W. N. Morris and L. H. Reyerson
Some Theoretical Discussions of Hypnotics...... ....Thomas C. Jaleski
*Some Effects of a Magnetic Field on the Spectra of Gases.........................John B. Dutcher
Measurement of Condenser and Coil Resistance by the Differential Thermometer Method..R. R. Ramsay

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* Papers starred not published in this Proceedings.

A Straight Line Frequency Audio Oscillator...R. R. Ramsay
Calibration of Ammeters at Radio Frequencies ....Herbert C. Hazel

ZOOLOGY

Insects of Indiana for 1926................J. J. Davis
Record of Indiana Dragonflies, II...B. E. Montgomery
Some Habits of the Garden Slug, *Limax maximus*..........................Clem O. Thompson
*Cytoplasmic Inclusions of the Male Germ Cells of the Toad-bug[3]...........................F. Payne
Raising Fleas for Laboratory Purposes...S. A. Rifenburgh
*On the Composition of Pancreatic Juice...L. J. Rettger
*The Normal School "Biological Reservation" at Allyndale............................L. J. Rettger
Agglutinin Production: Frequency of Injections Constant, Dosage and Total Amount Injected Varied.............................C. A. Behrens
*Cytology of Gynandromorphic Katydids..N. E. Pearson
Formation of the Intranuclear Rod in Succinea.......................................C. P. Hickman
Symptoms as Indicators...............Robert Hessler
Two Years Bird-banding at West Lafayette, Indiana...............................Louis A. Test
*Weights of Banded Birds...........Everett C. Myers
Notes on Some Birds of Anderson, Indiana..................................Charles Piper Smith
Gynandromorphic Earwigs.............W. P. Morgan
Hog Lungworms: Corrections of Previous Papers ....George Zebrowski
*The Spring Bird Fauna of Bloomington, Indiana ....Will Scott
Notes on Indiana Amphibians and Reptiles....................................George S. Myers
A Note on the Distribution of Earwigs...W. P. Morgan
Some Sources of Ornithological Material and What They Tell...................Amos W. Butler

6:00 p. m. Annual Academy Dinner.
Barton W. Evermann, Toastmaster.
7:30 p. m. Concert by Orchestra of Ball Teacher's College.
Courtesy Prof. C. E. Palmer, Conductor.
8:15 p. m. *Illustrated Lecture, "The First Greenland Expedition of the University of Michigan", by Prof. W. H. Hobbs, University of Michigan.

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* Papers starred not published in this Proceedings.

[3] To be published in the Journal of Morphology.

SATURDAY, DECEMBER 4, 1926.

9:00 a. m. Trip to Ball Brothers Glass Factory and to other Manufacturing Plants.

9:00 a. m. High School Section.

*The Indiana Academy of Science and High School Teachers of Science..................W. T. Blanchard

*The Training of High School Teachers of Science.... ....F. B. Wade

*Biology, After Four O'Clock..............Joel W. Hadley

*Improving the Teaching of Science in the High School, Round Table Discussion.

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* Papers starred not published in this Proceedings.

MINUTES OF THE EXECUTIVE COMMITTEE

DECEMBER 2, 1926.

The Executive Committee was called to order by President Blanchard at 8:15 p. m. in the Hotel Hoberts. The following members were present: F. M. Andrews, C. A. Behrens, W. M. Blanchard, F. J. Breeze, H. L. Bruner, W. A. Cogshall, Stanley Coulter, E. R. Cumings, J. J. Davis, C. C. Deam, H. F. Dietz, H. E. Enders, A. L. Foley, R. C. Friesner, W. N. Logan, W. J. Moenkhaus, W. P. Morgan, D. M. Mottier, E. B. Williamson and J. S. Wright.

The minutes of the spring meeting were read and approved.

Reports of officers were as follows:

Report of Treasurer.—

December 1, 1925, balance in treasury	$405 30
Dues collected, December 1, 1925-December 1, 1926	753 00
Total	$1,158 30
Total expenditures	582 85
Balance, December 1, 1926	$575 45

Upon motion duly seconded and passed the report was accepted.

Upon recommendation of the Treasurer the Committee voted to transfer $200 from the General Fund to the Endowment Fund.

Press Secretary.—H. F. Dietz, Press Secretary, reported excellent co-operation on the part of the press, both in Indianapolis and throughout the State. He pointed out that contributors could help very materially in the work of publicity if they would send him abstracts of their papers, since he is continually being asked for publicity statements concerning papers on the program. The report was accepted with thanks.

Editor.—J. J. Davis reported as follows:

Volume 35 of the Proceeding's of the Indiana Academy of Science was distributed September 21, 1926. The editor used every means that time and opportunity would permit to secure better printing service but was unsuccessful. The state printers have repeatedly laid aside the Proceedings to handle some other publication of less importance and no more urgent than our own. We would therefore recommend that the resolutions committee take cognizance of this situation and that the State Printing Board be strongly advised of the unsatisfactory situation.

The cost of the 1925 Proceedings was somewhat less than the 1924 Proceedings because of the fewer pages.

	1923	1924	1925
Cost	$1,282.18	$1,668.64	$1,404.80
Number copies	1,000	1,300	1,300
Number pages	336	428	393
Number cuts	74	107	61
Kind of binding	Paper	Cloth	Cloth

The financial report, not including clerical help and other editorial expenses, as follows:

STATE FUNDS.

Annual Appropriation for 1925 Proceedings		$1,200 00
Cost of 1925 Proceedings	$1,404 80	
Balance due, paid from sale of reprints		204 80
		$1,404 80

REPRINT ACCOUNT.*

Balance from 1924 Fund		$157 23
Received from authors for reprints		297 46
Total		$454 69
Total funds available (Brought fwd.)		$454 69
Paid Burford for extra reprints	$141 86	
Paid Burford for extra cost of Proceedings	204 80	
Photographic work (3 bills)	2 80	
Express and postage not elsewhere charged	7 93	
	$357 39	357 39
Balance in Reprint Fund		97 30
Balance due for reprints		17 50
Total		$114 85

Program.—Chairman Breeze presented the program of papers and meetings to be held on Friday and Saturday.

Academy Foundation.—Chairman Butler gave the following report:

December 1, 1925, balance on hand	$68 67
Total receipts, including cash for U. S. L. L. bond due	464 06
Total	$532 73
Total investments including accrued interest made during year	451 67
Balance on hand December 1, 1926	$81 06

ASSETS.

Railroadmen's Building and Savings Association, 6%	$900 00
Muncie Masonic Temple Preferred, 5½%	200 00
U. S. 4th L. L. Bonds, 4¼%	100 00
Balance shown above	81 06
Total Assets	$1,281 06

Report was accepted with thanks.

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* A charge was made for reprints in order to add to the available publishing fund.

Biological Survey.—Chairman Dietz reported a number of survey papers recently published and others in the process of publication by members of the Academy. Among those mentioned as completed or in the process were:

Blatchley's, Heteroptera of Eastern United States.
Montgomery's, Studies of Indiana Dragonflies.
Deam's, Grasses and Sedges of Indiana.
Myer's, Reptiles of Indiana.

Attention was called to the fact that papers of a survey nature and exhibiting high grade work would be given recognition by the Conservation Commission.

A motion was passed asking the Committee on Biological Survey to take action with regard to obtaining certain information of a survey nature by questionnaire as requested in a motion presented and passed at the annual meeting a year ago (see Proceedings, vol. 35, page 22).

Research Committee.—Chairman Foley of the research committee reported an increase in interest shown by manufacturers and the public by way of submitting technical problems to the committee for solution. He reported 18 such problems for the year. Of these, eight have already been solved, six were referred to other institutions for solution, and four were in the process of solution at present.

A motion was passed to have a report of this work published in the next volume of the Proceedings.

Archeological Survey.—Chairman Logan reported five mounds opened in the vicinity of Worthington, Indiana. He reported that "skeletons, charcoal, pottery fragments, arrow points, and other artifacts were taken and added to the local collection." Three other mounds were sectioned but contained no remains. The chairman of this committee also assisted in the excavation of the Albee Mound located near the Sullivan-Vigo line in the Wabash Valley. This investigation was made on the basis of a plan of co-operation between the Division of Geology and the Historical Bureau. The Chairman, assisted by Mr. E. Y. Guernsey, a member of the committee, made a study of the material collected and classified them. The skeletal materials and artifacts obtained are now a part of the collection in the State Museum.

State Library.—Chairman Dietz reported extremely cramped conditions at the State Library. He called attention especially to the lack of space for the proper handling of the library material belonging to the Academy.

The question of the proper housing of the library and museum materials was referred to the committees on Relation of Academy to State and on State Library for immediate action.

Relation of Academy to State.—In the absence of Chairman Wallace, H. F. Dietz reported that a report and request for additional appropriations had been very carefully worked out by Treasurer Enders in which he very skillfully presented the Academy's cause. Chairman Wallace had presented this to the Budget Committee of the State Legislature and expressed the hope of favorable action.

Membership Committee.—Chairman Enders of the Membership Committee reported that 45 applications for membership were then in his hands. These names were not read, but were held over to the final business session of the meetings for action.

New Business.—The science faculty of Notre Dame University extended an invitation for the next winter meeting of the Academy to be held at that institution. The invitation was recommended for action to the general session of Friday morning.

Doctor Rettger made a recommendation to the Program Committee for next year that a new section on Bacteriology, Physiology, and Hygiene be established on the program of sectional meetings. A general discussion of the congestion on the program and lack of time for discussion of papers followed.

The Program Committee was requested to bring in a report at the Friday morning business session concerning the advisability of having a two-day session for the reading of papers.

A motion was made to amend section 2 of the By-Laws to read as follows, "The President shall deliver a public address at one of the sessions of the Winter Meetings of the Academy at the expiration of his term of office." This was referred for action to the business session of Friday morning.

President Blanchard appointed the following committee on resolutions: E. B. Williamson, E. M. Bruce, and F. Payne.

Chairman Enders of the Membership Committee read the following names recommended by his committee for Fellows in the Academy:

Marcus W. Lyon, Jr., South Bend,
Edwin M. Bruce, Terre Haute,
J. E. Switzer, Bloomington,
O. B. Christie, Muncie,
George Hoffer, West Lafayette.

Upon motion duly seconded and passed these members were elected to Fellowship in the Academy.

MINUTES OF THE GENERAL SESSION.

DECEMBER, 3, 1926.

The General Session was called to order by President Blanchard at 9:30 a. m.

Minutes of the Executive Committee were read and approved.

Attention was called to a previous invitation to the Academy to hold its next meetings at Indiana University. Professor Rettger moved that inasmuch as we have never met previously at Notre Dame University the invitation to meet at that institution be accepted. Motion was passed.

Section 2 of By-Laws was amended in accordance with recommendation of the Executive Committee. See above minutes.

Chairman Breeze of the Program Committee made the following recommendations for future programs:

1. That the printed programs give names of institutions of the persons presenting the papers.

2. That the first general session begin promptly at 9:00 a. m.

3. That in case of more than one paper by a given individual the additional paper or papers be dropped to the end of the program in order of receipt.

4. That the President shall deliver his presidential address at any one of the general sessions.

5. That the Academy issue an invitation to the local state branches of the Mathematical Society, local sections of the American Chemical Society, and members of the medical profession to join with the Academy in their annual meetings.

This report was adopted as presented.

Upon motion duly seconded and passed the members recommended by the Executive Committee as Fellows were declared elected.

The following nominating committee was appointed to report at the business session following the annual dinner: Foley, Bruner, and Williamson.

Chairman Enders of the Membership Committee reported 56 names as candidates for membership in the Academy. These were read and voted into membership by the general session.

Business session was adjourned and the reading of papers followed.

At a brief business session following the annual dinner the following business was transacted:

Committee on Resolutions made the following report:

"Inasmuch as we have been so courteously received and entertained by our hosts, The Ball Teachers' College and the City of Muncie, we wish to extend to them our sincere thanks for these courtesies."

The report was unanimously accepted.

The nominating committee made the following recommendations for officers for the year 1927:

President, Frank B. Wade, Indianapolis.
Vice-President, Fred J. Breeze, Muncie.
Secretary, Ray C. Friesner, Indianapolis.
Assistant Secretary, W. P. Morgan, Indianapolis.
Treasurer, Marcus W. Lyon, Jr., South Bend.
Press Secretary, Harry F. Dietz, Indianapolis.
Assistant Press Secretary, J. A. Nieuwland, Notre Dame.
Editor, J. J. Davis, West Lafayette.

By action of the session these officers were declared elected.

Chairman Enders of the Membership Committee reported a number of additional names as applicants for membership. These were read and declared elected. Names of all new members elected during these meetings follow:—(98 in all)

Allen, Dorothy, Asst. in Botany, 1522 N. Tuxedo, Indianapolis.
Allibach, Theodore, Chemist, 120 Quincy St., West Lafayette.
Alter, Chester M., Chemistry, 909 University, Muncie.

Alquist, Francis N., Chemistry, 216 Russell St., Lafayette.
Amidii, Terzo Paul, Botany, Bloomington.
Austin, Raybrom C., Physiology, 311 E. Smith, Bloomington.
Babcock, Clarence, Physics, Muncie.
Barkley, Grace, Botany, 107 S. College, Greencastle.
Beebe, Ralph E., Chemistry, 726 Ashland, Muncie.
Bell, Bessie, Botany, Logansport.
Bennett, Wallace, Chemistry, 5 Waldron, West Lafayette.
Benson, Wallace F., Chemistry, 215 Columbia, W. Lafayette.
Betzner, Ruth A., Botany, Bunker Hill.
Bockstahler, Harold W., Botany, 27 Russell St., W. Lafayette.
Bolinger, Maurice G., Chemistry, 140 N. Grant, W. Lafayette.
Brackmeier, Gladys H., Geology, 708 Woodlawn, Bloomington.
Brinton, Howard H., Physics, 403 College, Richmond.
Brown, Roy E., Biology, 421 S. Fourth, Lafayette.
Burmaster, Rosa M., Geography, 219½ S. Jefferson, Muncie.
Carpenter, F. F., Zoology, Thorntown.
Childs, Lewis, Geology, 213 N. Grant, Bloomington.
Cooper, Delmer C., Botany, 29 N. Salisbury, W. Lafayette.
Copeland, Joseph J., Biology, Earlham College, Richmond.
Cramer, Paul, Mathematics, 216 Russell, W. Lafayette.
DeVries, Thomas, Chemistry, 139 S. Grant, W. Lafayette.
Eaton, Harold S., Botany-Chemistry, 502 S. Woodlawn, Bloomington.
Fillingham, Judith, Zoology, 1218 Broadway, Vincennes.
Fischer, George W., Botany, 5637 N. Penn., Indianapolis.
Fish, William E., Chemistry, 220 Waldron, W. Lafayette.
Fletcher, Worth A., Chemistry, 744 E. Third, Bloomington.
German, F. A. O., Chemistry, Valparaiso University, Valparaiso.
Gibbons, Robert C., Chemistry, 140 Pierce, West Lafayette.
Gorhorn, Benjamin, Geology, 117 S. Alabama, Brazil.
Hazard, Clifton T., Mathematics, 344 N. W. Avenue, W. Lafayette.
Heck, Joseph E., Chemistry, 447 Vine, W. Lafayette.
Headlee, W. Hugh, Botany, Earlham College, Richmond.
Hershman, J. Bernard, Physics, 305 Monroe, Valparaiso.
Hiatt, Lee Atta, Geology, 233 E. Arch, Portland.
Hile, Ralph O., Zoology, 429 E. Seventh, Bloomington.
Holl, Carl W., Chemistry, North Manchester.
Johnson, William, Botany, 3645 N. Denny, Indianapolis.
Jordan, William, Mathematics, 119 First, Oakland City.
Kepley, Charles L., Chemistry, 619½ W. Howard, Muncie.
Kintner, Edward, Biology, 1004 East, North Manchester.
Kraybill, Henry R., Chemistry, 615 University, W. Lafayette.
Lancaster, Forrest W., Physics, 1421 Congress, W. Lafayette.
Leach, William J., Zoology, Fowlerton.
Lee, Charles O., Pharmacy, 208 Sylvia, W. Lafayette.
Lefler, Ralph W., Physics, 1212 Atwater, Bloomington.
Little, Neil, Mathematics, 300 Sylvia, W. Lafayette.
Long, Betty, Botany, Memorial Hall, Bloomington.
Long, Gertrude, Biology, 2111 S. Jefferson, Muncie.

Mallon, Marguerite G., Home Economics, 249 Littleton, Lafayette.
Marting, Dorsey, Biology, English.
Martin, Frank D., Chemistry, 202 North, W. Lafayette.
Martin, Lawrence, Chemistry, 681½ Wabash, Terre Haute.
Matchett, John R., Chemistry, 120 Quincy, W. Lafayette.
May, Ansley I., Physics, 515 W. Main, Boonville.
Maxwell, Harold L., Chemistry, Agric. Exp. Sta., W. Lafayette.
McClintock, Ralph B., Geology, R. R. 6, Bloomington.
Merry, Jesse Belle, Botany, 650 E. 13th, Indianapolis.
Meyer, A. H., Geology, Zoology, 505 Calumet, Valparaiso.
Miller, Oran E., Physics, 112 North, W. Lafayette.
Miller, Sayers J., Medicine, 1009 S. 12th, Lafayette.
Moore, Richard B., Chemistry, 534 Hayes, W. Lafayette.
Nipper, W. Ward, Physics, 348 State, W. Lafayette.
Ossenberg, June E., Chemistry, 139 E. Walnut, Martinsville.
Packard, C. M., Entomology, Box 495, W. Lafayette.
Painter, Louise, Geography, Springport.
Pittenger, John S., Mathematics, 700 E. Eighth, Bloomington.
Pittenger, Lemuel A., Education, Selma.
Poffenberger, John, Student, Butler.
Powell, Horace M., Bacteriology, 5807 Lowell, Indianapolis.
Price, Gladys, Botany, 334 S. Dunn, Bloomington.
Railsback, Fern L., Botany, 417 Webster, Plymouth.
Randolph, Thorne F., Chemistry, Franklin.
Richter, Arthur, Botany-Chemistry, Jasper.
Ross, Oran E., Jr., Pharmacy, 226 Washington, Winchester.
Rothrock, Henry S., Chemistry, 152 Sheetz, W. Lafayette.
Schafer, Pearl C., Botany, Bremen.
Settle, Ralph D., Physics, Petroleum.
Shaw, R. William, Physics, 306 Salisbury, W. Lafayette.
Small, Virginia, Zoology, 202 Washington Place, Indianapolis.
Snowden, Gale, Botany-Geography, R. R. 3, Huntington.
Spieth, Herman, Zoology, Charleston.
Swain, Jesse A., 108 E. Monroe, Alexandria.
Sweeney, Elmer D., Botany-Zoology, 300 S. Green, Crawfordsville.
Swim, Floyd R., Chemistry, 103 Russell, W. Lafayette.
Teder, John H., Botany-Physics, Jasper.
Thacker, Henry H., Geology-Anthropology, 719 W. Walnut, Brazil.
Thatcher, Everett W., Physics, 165 Littleton, W. Lafayette.
Thomas, Dorothy A., Geography, 405 E. High, Portland.
Wilcox, Ralph F., Forestry, State House, Indianapolis.
Wilson, Cyril Michael, Botany, Jasper.
Wright, Emerson B., Botany, 4250 Central, Indianapolis.
Zetterberg, Edward, Chemistry, 646½ N. Elm, Muncie.
Newton, Roy F., Chemistry, 526 Hayes, W. Lafayette.
Wimmer, Merle, Biology, R. R. 1, Greentown.

Authorized by motion, the Secretary cast the ballot for the above named candidates.

President Blanchard introduced Barton W. Evermann, Toastmaster. The spirit of the toasts was for better science education for the youth of America.

Following the dinner members enjoyed a most excellent program of music in the High School auditorium given by the Orchestra of Ball Teachers' College through the courtesy of Prof. C. E. Palmer, Conductor.

At 8:15 Professor W. H. Hobbs, of the University of Michigan lectured on the First Greenland Expedition of the University of Michigan. The lecture was illustrated with motion pictures and was enjoyed by all.

RAY C. FRIESNER,
Secretary.

CLARENCE ABIATHAR WALDO.

HAMMOND, NEW YORK, JUNE 21, 1852.
BRIDGEPORT, CONNECTICUT. OCTOBER 1, 1926.

A.B. Wesleyan University, Middletown, Connecticut, 1875; A.M. 1878; Ph.D. Syracuse University, 1894.

Instructor in Mathematics and Registrar, Wesleyan University, 1877-81.

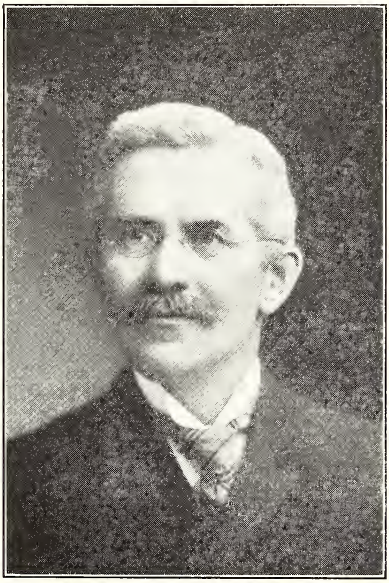
Professor of Mathematics, Rose Polytechnic Institute, 1883-91.

Acting President, Rose Polytechnic Institute, 1885-86 and 1888-89.

Professor of Mathematics, DePauw University, 1891-95.

Professor of Mathematics, Purdue University, 1895-1908.

Thayer Professor of Mathematics and Applied Mechanics, Washington University, St. Louis, Missouri, 1908-1917; Professor Emeritus, 1917-26.



CLARENCE ABIATHAR WALDO
1852-1926

This record shows that 25 years of Professor Waldo's life were spent in Indiana. It is doubtful, if within that period, any other college professor impressed himself so strongly upon the educational and religious life of the State. While this may have been due in part to the fact that he was connected with three of the institutions of the State, giving him an exceptionally wide acquaintance with college faculties and college student bodies, it was far more largely due to his personality, courteous and genial manner, enthusiasm in his work, keen interest in the work of others, and willingness to bear burdens in the furtherance of any good cause. He thus lost no opportunity of coming into intimate and sympathetic touch with those of like purposes and ideals. These associations not only enriched his own life, but they also made him a wise adviser and counselor of others.

The wide range of his interests and the scope of the tasks which he set for himself may perhaps be best shown by the organizations with which he was connected.

Fellow of American Association for Advancement of Science; Vice-President, Section D (Mathematics) 1902-03; Secretary of Council, 1903-04.
Fellow of Indiana Academy of Science; President, 1898; Editor of Proceedings, 1896 to 1898.
Society for the Promotion of Engineering Education; Editor of Proceedings, 1901, '02, and '03.
Indiana College Association; President, 1893.
North Central Association of Colleges and Secondary Schools; Mathematical Society of America; American Association of University Professors; National Geographic Society; Phi Beta Kappa; Sigma Xi; and Alpha Delta Phi.

The notations, which I am sure are incomplete, show that he was an active, working member in these associations, and the offices which he held in them show him to have been as effective as active. He never, so far as I can recall, missed any of the meetings of this Academy. By his formal contributions, by his participation in discussions, by his counsels in the Executive Committee and by his sheer joy in good fellowship he did much to mould the Academy into its present form.

Nor did Professor Waldo cease working after he had retired from active university duties. We find him in 1917 and 1918 working on four Exemption Boards in New York City, a patriotic service. Later, conducting a City (New York) Survey for the League of Churches, and acting as Emergency War Secretary for the Board of Education of the Methodist Episcopal Church. To those of us who knew him intimately these continued labors seemed but another proof of his amazing energy and willingness to serve. In these fields he doubtless made contributions as marked and rendered service as faithful and outstanding as in his teaching years.

While Professor Waldo published notable text-books and scientific articles and was in constant demand as a lecturer, he was at heart a *teacher*. To his students he gave his best and his best was marvelously good. That he himself felt he would be remembered as a teacher is shown by the following extract from a personal sketch of his life prepared at the request of a friend:

"My greatest contribution to education has been my intimate contact with thousands of young men during their college period. These are now scattered everywhere over the United States, yet always my earnest and devoted friends. These are my intellectual children whose ideals I have helped to form. *As a teacher of men I will be best known and remembered.*"

That Professor Waldo measured his life work correctly is clearly shown by the following extracts from letters from former students:

"He was one of the few strong men who have profoundly influenced my life." A graduate of Rose Polytechnic.

A former student of DePauw University wrote him: "It is now thirteen years since I had Determinants under you at DePauw and in all that time I have had no occasion to use them until today. * * * Today I had a problem in which Determinants proved a short cut worth the using. That after a few days of class drill, followed by a dormant period of thirteen years I am still able to use the method with facility is such a tribute to the skill with which the principle was laid down, that I pass the bouquet along to you."

At his funeral a former Purdue student exclaimed,—"Professor Waldo simply made me".

Such tributes might be multiplied indefinitely, and we may feel sure that Professor Waldo valued more highly the love and affection of his thousands of "intellectual children" than he would have valued great wealth. The peculiar feature of Professor Waldo's teaching lay in the fact that he not merely *imparted instruction*, but that he also *imparted character.*

And this was doubtless due to the fact that Professor Waldo was of a deeply religious nature. Righteousness, cleanness, the fine integrities of life appealed to him strongly and constantly. In his every public utterance this basic note rang out clearly and strongly. In the communities in which he lived he was both an intellectual and moral force. He worked in and loved the church. He worked in and loved the Y. M. C. A. Secretary Stacy writes,—"He never knew the inspiration and help he was to me as a young secretary. I am sixty now myself but I have never lost my appreciation of his life and work."

Professor Waldo travelled extensively. He was, after graduation, a student at the Universities of Leipsic and Munich. Later, he conducted many parties on extended European tours.

In his university relations Professor Waldo was more than a teacher. His interest in student life led him to an intelligent and comprehensive study of intercollegiate athletics and as a result a great mass of work fell to his lot, because of his intimate knowledge of this much-discussed problem. He was a member of the Faculty Athletic Committee in every institution with which he was connected; he was Arbitrator of the Big Ten Conference from 1901 to 1912, and Arbitrator of the Ohio Conference Colleges from 1903 to 1905. In this capacity he made far-reaching decisions and prepared many extended and important reports. His work did much to put intercollegiate athletics upon a clean and sportsmanlike basis. The present status of intercollegiate athletics is largely due to his painstaking and conscientious work.

It is perhaps out of place in this connection to speak of the home life of Professor Waldo, and yet those of us who knew it, realize how strong a factor it was in enabling him not merely to become the man he was, but also to accomplish what he did. He was married to Abby Wright Allen, August 2, 1881. Their only living child Alice Goddard Waldo is now a teacher in the Low-Heywood School at Stamford, Connecticut. Both wife and daughter entered into Professor Waldo's work in an effective and stimulating way, making possible by their sympathetic co-operation the vast amount of work he was able to accomplish.

A fine life purpose, finely and loyally carried to its fullest fruition is the memory that abides with us. I regret that the bibliography attached is incomplete, because of lack of time to secure needed data. It is hoped that at a later date these defects may be remedied.

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STANLEY COULTER,
Lafayette.

ROBERT WESLEY McBRIDE.

BARNES, OHIO, INDIANAPOLIS, INDIANA.
JANUARY 25, 1842. MAY 15, 1926.

Robert Wesley McBride, who for nearly 40 years was my friend and neighbor, attained recognition as a soldier, attorney, naturalist, and man of the world. I wish to speak of him principally as a naturalist, as a friend, and as a man.

In public service Judge McBride was a member of the Indiana National Guard from 1879 to 1893, first as a Captain and later with the rank of Colonel. He was always prominent in the G. A. R. and at the time of his death was Judge Advocate General of the National G. A. R. He was one of the surviving members of the personal bodyguard of President Lincoln and was author of an interesting book "Personal Recollections of Abraham Lincoln." He was also active in Masonic circles.

ROBERT WESLEY MCBRIDE
1842-1926

In official life he served as Judge of the 35th Judicial Circuit Court from 1882 to 1890. In 1890 he was appointed judge of the Supreme Court of Indiana, which office he held till 1893 when he retired to resume the private practice of law.

For a number of years after the close of the Civil War Judge McBride was in a seriously crippled condition and could get about only

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with the aid of both a cane and a crutch, but, in spite of this handicap, he had, prior to 1876, done considerable exploring among the earthworks, mounds and fortifications left by the mound builders, in the northeastern counties of Indiana. Anthropology was thus the first line he took up seriously. This soon was followed by Paleontology and Geology, insofar as they bore any relation to the study and evolution of man. He never "dabbled" in anything. When he undertook the study of any particular line, he stuck to it until he could qualify as an expert, but, as all the many forms of natural life are so closely correlated, he readily understood that a profound knowledge of "Natural History" in general was necessary. This knowledge he proceeded to acquire by taking up, successively, Entomology, Ornithology, Mammalogy, Botany and Organic Chemistry. On each subject he spent in time probably more years than are required for a college education. He never really dropped any subject but, when satisfied with his proficiency in that particular branch, would tackle the next one as his "major subject", keeping up the others more as side lines.

He became an accomplished taxidermist and mounted hundreds of native birds. Most of his early collecting and studying was done in the counties of Dekalb, Steuben, LaGrange and Elkhart, with occasional trips to the far West, to Michigan, Arkansas and, of late years, to Florida.

When, in December, 1885, the Indiana Academy of Science was founded, R. W. McBride, then living at Elkhart, became a charter member, and in 1916 was made a fellow. As long as he was physically able he made it a point to attend the meetings of the Academy each year.

In 1886 he and others founded the Indiana Audubon Society, of which he became the first president. The Society holds annual meetings at some point in the State, and these meetings he also attended on every possible occasion.

After his removal to Indianapolis Judge McBride gave more attention to the study and protection of birds and wild flowers than to some of the other branches of natural history. Before the Nature Study Club was founded by Mr. Woollen, he and I took many short outings together, to points adjacent to Indianapolis, in search of insects and shells and to study the wild flowers where they grew and the birds in their chosen haunts. On these outings we were sometimes accompanied by his three grandsons—now men— who then were keen of eye and full of joy and enthusiasm, as are all boys of their age. But their eyes were no keener and their joys no greater than those of their grandsire when an interesting "bug" or shell was brought to light or a rare bird or plant was noted. He would not allow them to pull the wild flowers or harm a snake or other reptile. On these trips and on others he often took a trowel and unearthed and brought home rare plants which he transplanted in the spacious back yard of his Park Avenue home. There he had many wild flowers growing, a number of which, owing to the greed and thoughtlessness of many joy-riders of today, are now almost or wholly extinct within the bounds of the State.

After the founding of the Nature Study Club, and while its members were comparatively few and its outings confined to the vicinity of Indianapolis, Judge McBride, despite his years and lameness, was often an enthusiastic member of the little band that tramped the fields and woods in search of first-hand knowledge. It was there that his powers of observation and his knowledge of the many forms of life happened upon, were especially notable; there that the title of "naturalist" was of him shown to be apt and worthily bestowed.

What is a naturalist? On whom should that title be rightfully bestowed? That question can most easily be answered by naming some of the naturalists of the past and present. Linnaeus, Darwin, Huxley, Agassiz, Say, Nuttall, Rafinesque, Audubon, Thoreau, Leconte, Baird, Cope and Jordan—they were all great naturalists of the world at large. In a minor degree, but still naturalists withal may be mentioned Evermann, Brayton, Coulter, Scoville, Butler, Cox, Hubbard, Duden, Hessler, Woollen, Wynn and McBride of our own Indiana. They were and are men who knew not fossils alone, not fishes alone, not birds alone, not plants alone, but who had or have a broad knowledge of the varied forms of life, both past and present, which are or have been parasitic on the crust of good old Mother Earth. They knew the close relationship and interdependence existing among all animate and inanimate things. They realized that this world—this universe of ours—is not composed of single isolated objects and forces but that each object, each force is but a necessary part of one grand and perfect whole.

Judge McBride was a man who, knowing these things, could impart in simple and easily understood language, his thoughts and his knowledge unto others. He was a man who could

"Go to the God of the wood
To fetch his word to men."

Judge McBride was ever a busy man. He, as do most naturalists, came in time to realize that our years, our time, is our only true possession here on earth. We bring nothing with us when we arrive. We can take nothing with us when we depart. In the interval between the days of our coming and our going we therefore, if a measure of success is to be ours, both hope and toil—for

"Joy's soul lies in the doing,
And the rapture of pursuing is the prize."

Three great evil spirits are abroad in this land today—not only abroad but in many places have seemingly gained control. These are the spirit of intolerance, the lust for wealth and the desecration of nature's beauty spots, in order to satisfy that lust. Judge McBride was outspoken against all of these. He was a man of tolerance, rightfully believing that the only true measure of a man is to be judged by his moral character, his willingness to at all times abide by the Golden Rule and the laws of his country, and his willingness and ability to do what he can, whenever he can, to advance the moral and material prosperity of mankind. A man's creed—no other man should question—the color of his skin no man can govern. Hence, here in America—the "land of the free"—Jew and Gentile, Catholic and Protestant, Negro and Jap—should stand equal before the law and in the eyes of his fellow men—and all were the friends of R. W. McBride.

The lust for great wealth we see on every hand, and the Judge has often spoken with me against it. No true naturalist was ever an incessant seeker after a fortune. Of a thousand men, one looks up into the sky and wonders why it is there—looks out into space and ponders o'er the porch lights of other sun-ruled systems—treads the earth and thinks of her as a moving sphere—the others look down upon her streets and pathways—seeking gold. Judge McBride was the thousandth man. Because a few of his friends belonging to the other horde became in time plutocrats, he did not regard them as worthy of great deference. He sought not great wealth nor fawned upon those who possessed it. He doffed his hat to no man-made, so-called statesman or ruler, to no millionaire because he was such, to no autocrat whose only claim to greatness was that he was a descendant of some magnate of long ago—but only to the flag of his country, to death in its majesty and to those who by their accomplished deeds had proven that to them belongs rightfully the privilege of receiving the deference of their fellow men.

Against the desecration of Nature, either by the thoughtless who kill birds and reptiles for the mere sport of killing, or destroy the wild flowers to satisfy a moment's desire of possession, Judge McBride was ever outspoken. More so was he against those who, in a larger degree, rape ruthlessly the beauty spots of Nature in order to extend the bounds of our so-called civilization and at the same time satisfy their lust for wealth.

I have thus treated briefly the outstanding traits of Robert W. McBride, as a naturalist, a friend and a man. A genial, upright, kindly, noble man has gone. Long will his memory last among those who, like myself, enjoyed the precious privilege of his friendship.

W. S. BLATCHLEY,
Indianapolis.

CHARLES MARQUIS SMITH.

RACINE, WISCONSIN. RACINE, WISCONSIN.
SEPTEMBER 28, 1872. JULY 27, 1926.

Charles Marquis Smith was born in Racine, Wisconsin, September 28, 1872. After graduating from the public schools of Racine he entered the University of Wisconsin in the fall of 1892 and graduated in 1896. He was a graduate student at the same institution from 1897 to 1899, his major subject being Physics. He continued his graduate work in Physics at the University of Munich during the year 1900-1901 and the summer of 1904, having courses with Roentgen and Eberts.

While doing graduate work at the University of Wisconsin, professor Smith was a member of the instructional staff and assisted at the Astronomical Observatory. It was likely here that he developed that interest in astronomy which stayed with him in later years. In the fall of 1901 he came to Purdue University where, for 25 years, he was an esteemed and valued member of the teaching staff of the Department of Physics.

In connection with the teaching of Electrical Measurements to engineering students Professor Smith wrote a text, "Electric and Magnetic Measurements", which is still widely used.

During the World War he was for a time connected with the Bureau of Standards at Washington, D. C., where he helped in the preparation of a text on "Radio" for use in the army and the navy training schools.

Professor Smith was elected to membership in the Indiana Academy of Science in 1910 and to fellowship in 1912. At the time of his death he was treasurer of the organization. He was an active worker in the interests of the society, always attending its meetings and seeking worthy candidates for membership. He was a member of the American Physical Society, American Association for the Advancement of Science, American Association of University Professors and Sigma Xi, having held offices in the local chapters of the last two named societies.

Professor Smith was a rare type of the gentleman and the scholar. He loved the companionship of his fellows and had a rare appreciation for the beauties of nature. He was loyal to the institution he served and to his own high ideals of life and conduct. Students found in him, not only a teacher of inspiring personality, but a friend and valued counsellor. His thoughtful consideration of others, especially those in the humbler walks of life, was a distinguishing characteristic.

His interests extended outside the University and every movement for the betterment of the community received his hearty support and co-operation.

By his untimely death July 27, 1926, the University has lost a valued instructor and his colleagues a lovable friend.

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W. H. BAIR,
Purdue University.

PRESIDENT'S ADDRESS

THE UNSELFISH SERVICE OF SCIENCE.

W. M. BLANCHARD, DePauw University.

Fellow Members of the Indiana Academy of Science: In obedience to a well established custom I solicit your patient indulgence while I attempt to present in a few brief paragraphs what may be charitably designated the Academy President's retiring address. I shall make no apology if my remarks are suggestive of an appeal to the emotions rather than an effort to bring new knowledge for, in all frankness, it is my desire in at least some small measure to stimulate your pride, to encourage your faith, and to confirm your unselfishness—your pride in the recorded achievements of science, your faith in the coming of far greater revelations and attainments, your unselfishness in the continued pursuit of truth and its application to the alleviation of the ills of mankind. Nor shall I make any apology for selecting as a kind of text for the basis of this appeal the words of a great teacher: "And ye shall know the truth and the truth shall make you free".

I appeal to your pride. To speak of making men free implies a state of bondage, and the history of *Homo Sapiens* is in fact a history of man's struggle for freedom. It was for freedom from the beasts of forest and jungle that he sought refuge in a cave and defended himself with clubs and stones. It was for freedom from the assaults of his own kind that he barricaded his hovel and defended his family from pillage and plunder. It was for freedom from social and political servitude that he joined the ranks of his suffering fellows and tore the scepter from the tyrant's hand. It was for freedom from religious tyranny when he defied the priest and the Pope and set his own conscience as the guardian of his religious opinions. It was for freedom from ignorance and superstition and fear that he faced the bewildering mysteries of natural forces and demanded the key to the chamber of knowledge. Through all the long ages of tradition and recorded history the struggle has continued, but it was not until the dawn of the nineteenth century that man moved rapidly into that larger realm of freedom that makes for longer life, loftier thinking, multiplied comforts, and a richer and happier intercourse between men of all nations, all races, all creeds.

And whence cometh so suddenly this larger freedom? "Ye shall know the truth and the truth shall make you free." 'Tis largely the fruit of the labor of the man of science. Repressed from age to age by the combined powers of intolerance, superstition, and selfishness, the spirit of inquiry at last burst upon the world and men went forth to uncover the hidden mysteries, to discover the secrets of earth and sky and the coming and the going of every living creature, from man to amoeba — macrocosm and microcosm — universes infinitely vast and

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planetary systems infinitely small—forces that tear asunder and forces that bind together—integration and disintegration—life, disease, and death—there is no species of matter, no living organism, no manifestation of energy, that the modern man of science has not faced, interrogated, and forced to yield at least a partial answer to his persistent demands for the truth.

So rapid has been the accumulation of knowledge and so vast has become the wealth of material that it has become necessary to divide and subdivide the fields of research and introduce from time to time new titles to designate these newer branches of science. Less than a dozen decades ago one small volume under the general title of Chemistry might have contained all the essentials of this infant science while today we are fairly bewildered with General Chemistry, Inorganic Chemistry, Organic Chemistry, Analytical Chemistry, Physical Chemistry, Industrial Chemistry, Electro Chemistry, Physiological Chemistry, Bio-Chemistry, Colloidal Chemistry—and this does not exhaust the roll. And within the lifetime of some of my hearers the term Biology might have covered the outstanding facts and principles of a science that has moved forward with such strides that its first offspring, Zoology and Botany, have each become the progenitor of a large and respectable family designated by such significant names as Taxonomy, Embryology, Cytology, Parasitology, Entomology, Morphology, Physiology, Ecology, Paleontology—and this list is not exhausted. And from the more staid and less elusive of the natural sciences—Geology—one gathers the classic sounding titles of Cosmical Geology, Geognesy, Dynamical Geology, Structural Geology, Palaeontological Geology, Stratigraphical Geology, Physiographical Geology, Economic Geology, and along with them Petrography, Mineralogy, and in more recent times Meteorology and Climatology. And these are not mere designations of chapters in a volume on chemistry or biology or geology, but each represents a vast accumulation of knowledge in a specialized field where men are still laboring with energy and enthusiasm. What man engaged in the pursuit of truth even in a very modest way does not experience a commendable sense of pride over the additions to human knowledge and the practical utilization of this knowledge that have been made by scientifically minded men these past three generations?

A few weeks ago more than a thousand chemists gathered at the last resting place of Joseph Priestley, in Northumberland County, Pennsylvania, to pay once again their tribute of respect and honor to the memory of a genial, modest natural philosopher whose simple discoveries a century and a half ago laid the foundations of the modern science of chemistry. It was at this same spot that a mere handful of chemists gathered fifty years ago, just one hundred years after the discovery of oxygen—gathered for the same purpose—and upon that little group fell the spirit of Priestley, and under the inspiration of that spirit was born the American Chemical Society, destined to become in less than two generations the largest single scientific organization in the world. One stands amazed at the growth of chemical science within the span of these few years. Although for awhile young men interested in chemistry continued to cross the sea to learn the methods of the recognized masters of chemical research in the old world, it was not long before our own universities became centers of productive chemistry and began to draw unto themselves their own. Today hundreds of students of other countries are themselves crossing the sea to learn of the masters in America. So evident have become the benefits of both pure and applied chemistry that little difficulty has been found in persuading men of wealth to contribute funds for the erection and equipment of the finest chemical laboratories in the world. The magnificent laboratories at Johns Hopkins, Cornell, Yale, Columbia, and the one projected at Harvard are evidences of the confirmed faith in the public benefit to be derived from systematic instruction and research in the field of chemistry. Furthermore, the promotion of chemical investigation by the larger industrial plants at the present time is a matter of favorable comment, for today steel mills, cement plants, dye manufacturers, pharmaceutical establishments, packing houses, and others too numerous to mention maintain a research force and well equipped laboratories for the purpose of solving technical as well as purely scientific problems and opening up new avenues for the application of science.

Nor is this interest and faith limited by any means to the field of chemistry. Research in the various fields of botany, zoology, geology, physics, and even astronomy is being encouraged and supported as never before. In state agricultural stations, state universities, privately endowed institutions, the various bureaus of the national government, and under the aid of various foundations established for public services by public spirited men—everywhere men are busy in every branch of science pushing back the frontier, extending the horizon, bringing to light new truths, discarding or recasting old theories, bringing forth new ones, and adding to and reorganizing the vast accumulations of knowledge.

A little more than a century ago John Dalton was modestly proposing a practical theory of atoms to explain and account for certain fundamental laws of chemistry. Today we have a vastly different theory of atoms and the physical chemist is calculating with some degree of boldness the orbits of the electrons in this microcosmic planetary system known as the atom and measuring the radiant energy produced by the jumping of the electron from one orbit to another. Tomorrow we shall be as familiar with the chemistry of electrons as we are now with the chemistry of molecules and atoms, and soon we may be making ready for the newer chemistry, the chemistry of a sub-electronic world.

Less than a century ago Wöhler was announcing the first synthesis of a natural organic compound while today thousands of such compounds adorn our chemical museums and find their application in the industrial world, while the bio-chemist is now isolating and synthesizing those marvelously active but very elusive products of the ductless glands which were not even known in the early days. From hormones and vitamines will soon be elicited their secrets and in the no distant future we may expect to learn the difference between the chemical composition of the proteins in pathogenic and non-toxic bacteria and be able to place chemotherapy and serotherapy in the category of exact sciences.

In patience and faith the man of science pursues his way and it not unfrequently happens that discoveries regarded at the time they are made as of little import lead eventually to astonishing results. It has been only a few years since tungsten was little more than a chemical curiosity; the light from hundreds of millions of incandescent lamps now attest the benefits derived from a more thorough acquaintance with its properties. Some sixty years ago the astrophysicist caught the glimmer of a new element in the chromosphere of the sun and named it helium; today pilots are crossing the continent in super-airships lifted by this same element extracted from the natural gas of Texas by the chemical engineer.

A century ago, by the most simple and elementary experiments, Faraday was digging out the fundamental connection between magnetism and electricity; while today man presses a button and the darkness of night is converted into the light of midday; he pulls a lever and electrical forces are set in motion that do the work of hundreds of thousands of men; he speaks into the air and his voice is heard across the sea.

Less than three generations ago, with testtube and beef broth Pasteur was destroying the belief in the spontaneity of life, demonstrating that life is generated from life, and bringing to light astonishing causes with equally astonishing preventatives of virulent diseases. Into this new field of research entered a host of young biologists and today the bacteriologist has robbed many a plague of its terrors, while the embryologist in his patient observations of germ cells and chromosomes and blastomeres is coming to some understanding of the deeper mysteries of life and the underlying principles of heredity, and steadily building for us a practical science of eugenics. Can disease be eradicated, senescence averted, death indefinitely postponed? Surely the combined labors of the bio-chemist and the pathologist are making notable strides in eliminating the causes of disease, while experimental zoology is slowly but surely unfolding the causes of the approach of old age and discovering the means by which we may greatly extend the span of human life. On the basis of the rate at which we have been increasing, during the past generation, the average length of human life, it is predicted that in 1930 it will be 61; in 1940, 65; in 1950, 69; in 1960, 72; in 1970, 75; in 1980, 78; in 1990, 80; in the year 2000, 82; while in 2100 nearly every one should live to be 94 years of age. To Prof. Irving Fisher is credited the statement that "the most sensational conclusion which science has ever reached is this: that life cells and many tissues of man are potentially immortal in the purely physical sense. There will be a time, perhaps, when men will live, if not forever, at least much longer than the century mark which is now practically the limit of the human life span." This rosy anticipation is prompted by such discoveries as that of Professor Woodruff of Yale, who found "that no natural death occurred in 8,500 generations of the minute organism, paramecium, a period of time equal to 250,000 years of human life"; that of Dr. Alexis Carrel of the Rockefeller Institute for Medical Research, who "has kept a chicken heart growing and alive for over fifteen years, an age that no chicken can attain;" and that of Professor Thomas H. Morgan of Columbia, who found "that 1/250 part of a worm will regenerate and become younger than the original worm." "The time will come perhaps", says Professor Fisher, "when the human being will have an indefinite life span, when his defective and worn-out parts can be replaced and renewed like those of a watch."

Is it strange, therefore, that the results of researches in science should excite our pride, a commendable pride, even though we ourselves may be only remotely connected with its actual progress? But all of us do have a part in this progress. The high school science teacher zealously laboring to awaken a spirit of inquiry in a thoughtless youth; the college instructor training the embryonic scientist in habits of close observation, exact measurement, and logical reasoning; the university professor suggesting the problems and directing the investigations of graduate students; the independent investigator in research foundations or technical laboratories devoting his whole time and strength to the pursuit of some bond of unity in a vast assemblage of bewildering data—all are making some contribution towards the attainment of the final goal, the knowledge of the truth that shall make men free.

How long will this scientific progress continue? Will the cunning to devise and the skill to execute increasingly intricate experiments never run their course? Will the imagination that "bodies forth the forms of things unknown" continue to fashion illuminating theories and guide men to ever increasing marvels of discovery? Is there no limit to the capacity of man's intellect to reproduce the thoughts of God expressed in nature's handiwork? Will the coming years like those now passing experience a constant succession of thrills over scientific discoveries and looking backward wonder that the years behind were relatively so poor in the rewards of scientific endeavor? Or has man reached the zenith of his ability to cope with the problems in the realm of science and arrived at the shores of a sea over which he has no craft to sail?

In an address on "The Evolution of Intelligence" delivered at Yale a few years ago President Angel raised this question: "Is the evolutionary process at an end so far as concerns the human brain and human intelligence?", and he followed the question with these statements: "Assuming some extra-mundane observer of the primeval slime out of which organic life has come, it would certainly have seemed to such an one grotesque to predict such changes as have actually come to pass, and particularly as regards intelligence. Similarly it is entirely impossible to surmise at what point progress beyond present human capacities may occur, but to conclude with any certainty that such further progress will not occur, much more that it cannot occur, seems hardly warranted. Whether this view regarding the further evolution of intrinsic human capacities is right or wrong, there would appear to be no practical limit to the changes which man can hope to bring about in the conditions of his life by the further application of the same technique which has produced the highest forms of modern civilization, has produced our fine arts, and, particularly, has produced our modern science. Conceivably we shall never have greater epic poetry than that of Homer, greater sculpture than that of Phidias, greater architecture than that of the Parthenon, greater drama than that of Shakespeare, greater painting than that of Raphael and Titian, greater symphonic music than that of Beethoven. There is, however, nothing to prevent advance upon such achievements and in the range of the natural sciences at least, thanks largely to the perfection of experimental technique and the utilization of mathematics, there seems to be literally no limit in sight to the further mastery which man may achieve over the forces of nature and consequently no limit to the alterations which he may be able to introduce to the enrichment of civilization."

And so *I appeal to your faith in the coming of yet larger things.* As vast as have been the accumulations of scientific knowledge these past seventy or eighty years, as wonderful as has been the development of scientific theories, as marvelous as has been the practical utilization of this knowledge and the application of these theories to the extension and enrichment of human life, far greater achievements are awaiting the men who are zealously devoted to the pursuit of truth.

It has been almost a hundred years since Liebig and Wöhler and a few other kindred spirits began their investigations in what might then have been called animal and vegetable chemistry in contradistinction to mineral chemistry. Little did they dream that in a few decades the development of synthetic organic chemistry would reach such proportions as to merit the encomium, "the eighth wonder of the world". The organic chemist had largely to do with substances, their composition and molecular structure, and the steps by which complex molecules could be constructed from simpler ones. He delighted to tackle the problem of reproducing the products of nature in plant and animal and was not baffled by the complexities of such substances as carbohydrates, proteins, tannins, camphor, indigo, or rubber. Theory and practice developed together and the linking of atoms, the benzene ring, isomerism, and stereoisomerism proved valuable mines from which many a priceless nugget was extracted. And then interest began to wane and one might have asked: has chemistry reached its climax, the chemist his limit? It was but the beginning of a new day, a change of direction rather than a halt in progress. It was the day that marked the beginning of a closer relation between chemistry and physics, the day when the chemist trained in physics as well as in chemistry, or the physicist trained in chemistry as well as in physics began to study the dynamics and kinetics of chemical reactions, the day that marked the birth of a new science—phsical chemistry—a science built upon the efforts to apply exact physical methods to the study of chemical reactions and to express results in mathematical terms. Chemical action rather than mere products elicited the chief attention and reversion, equilibrium, mass action, and ions vied with synthetic dyes and carbon rings in their contention for popular favor. Today the physical chemist still occupies the center of the stage and with his X-rays, cathode rays, electrons, radio-activity and all the other electrical phenomena associated with matter and the transformations of matter he seems to be pointing to the kaleidoscopic rearrangement of the various fragments of chemistry and physics into three distinct sciences: the science of gases, the science of liquids, and the science of solids. But suddenly there come intimations of a renewed activity in organic chemistry, for we are learning that not only can higher petroleum hydrocarbons be cracked—larger molecules broken down into smaller ones—but to these smaller molecules oxygen can be added, which means that petroleum is likely to become in the near future as prolific a source of synthetic wonders as the proverbial tar barrel. Not to be outdone, the physical chemist announces the discovery of a process of splitting hydrogen molecules into their atoms and the recombining of these hydrogen atoms into molecules with the production of a temperature of 7000 degrees Fahrenheit. This may prove to be but the beginning of another series of new wonders.

But the spirit of co-operation manifest between chemist and physicist is active in other quarters and with beneficial results. During the past twenty-five years, by a noiseless evolutionary process, botany and zoology have emerged from the category of descriptive into that of experimental sciences and they have begun to find a powerful ally in the science of chemistry. Is it not true that today it is the chemist who has been trained in biology as well as in chemistry, or perhaps the biologist who has been trained in chemistry as well as in biology who is attracting the greatest attention and making the most significant advances towards the discovery of the truth that shall make men free? Would a pure chemist or a pure biologist have discovered and synthesized adrenalin and thyroxin and isolated a vitamin or a hormone? Is it not the bio-chemist to whom we owe some of the most significant discoveries of very recent years and is it not in the realm of what is commonly called biology but through the labors of the bio-chemist in the study of chemical phenomena in the realm of living matter that we shall find the most valuable contributions to human knowledge during the next quarter of a century? Is it not true that just as the larger development of chemistry came from the co-operation of chemistry with physics so the larger and more fruitful development of biology is coming through the co-operation of biology with chemistry and physics?

It seems quite evident that there are two words that loom large when we are considering the advances in science anticipated in the near future—*specialization* and *co-operation*. An examination of the current literature of any branch of science confirms the impression that no one can hope to make any notable contribution toward this progress unless he has mastered the technique and become thoroughly acquainted with the known details in a very highly specialized field. To make any real discoveries, discoveries that really mark some advance in the development of science, necessitates intense specialization with reference to the problem attacked and the technique by which the data may be collected. But the investigator may be so completely submerged in his highly restricted field of investigation that he is unable to understand and evaluate new discoveries being made in other highly specialized fields. The result may be something like that of a widely scattered army on the march where the individual troops are beyond the sight of each other, with no communication between them and no commanding officer to maintain the whole line in an orderly and progressive movement. In order that the specialist may not be lost in this maze of specialization is it not essential, therefore, that the young men who are today cherishing hopes of making some contribution to this development of science be urged to take the time not merely to acquire a somewhat general acquaintance with, but to really master the outstanding facts and the fundamental methods and principles of the several sciences most nearly related to that in some restricted field of which they expect to labor for years to come?

And will it seem ludicrous to suggest that the world will be the richer if certain individuals of unusual intellectual capacity and brilliancy of imagination could be induced to dedicate themselves to the sole purpose of observing, correlating, and organizing these individual collections of knowledge being dug up by this increasing army of specialists? Unless these widely separated laborers in even a single science and the still more widely separated laborers in the several sciences are brought into a closer mutual acquaintance and can come to some understanding and appreciation of the deeper significance of the results of the labors of all the research workers, or unless we shall be able to find and lay hold of a few super-minds who will be able to unify and harmonize these individual accumulations of knowledge how shall we hope to make much further progress towards that day when men shall know the truth in its larger aspects, the truth that shall make men free?

But we look into the future with confidence. The advance in pure science these past seven decades has been so rapid and the practical utilization of scientific knowledge has been so extensive and so ingenious that the very momentum of this progressive movement will carry us far into the future. We entertain a lively faith that the most astonishing discoveries and applications are yet to come. Towards this end we must have ever increasing specialization but at the same time, in order that we may not be lost in a confusing mass of technical details, we must have at the same time more cooperative and unified effort on the part of the outstanding leaders of the different branches of science. New discoveries will necessitate the abandonment of some theories now regarded as well established but they will likewise bring us new vantage points from which to reorganize all of our knowledge and postulate other theories yet more comprehensive. In this connection we may all take to heart the sentiments expressed by Prof. Robert A. Millikan in one of the Terry Foundation Lectures delivered recently at Yale: "We had not come quite as near sounding the depths of the universe in 1900, even in the matter of fundamental physical principles as we thought we had. Today we can still look out with a sense of wonder and reverence upon the fundamental elements of the physical world as they have been revealed to us in the twentieth century. We know that the childish mechanical conceptions of the nineteenth century are grotesquely inadequate. We have now no one constant scheme of interpretation of physical phenomena and we have become wise enough to see and to admit that we have none. We have learned to work with new enthusiasm and new hope and new joy because there is still so much we do not understand and because we have actually succeeded in our lifetime in finding more new relations in physics than had come to light in all preceding ages put together, and because the stream of discovery as yet shows no sign of abatement."

And now I would close with a few words of appeal to your spirit of altruism for the title chosen for this very brief address is "the unselfish service of science." The scientist is the laborer and science is the fruit of his toil. In every age there have been at least a few unselfish souls who have endeavored to understand something of the world in which they lived. Moved by the spirit of curiosity and urged by a desire to know they have followed the stars across the firmament, observed the effects and sought the causes of the recurring seasons, taken cognizance of the crumbling rocks, noted the life history of beast and bird and flower, and with kettle and alembic in dark cellars and smoky kitchens they have tried to extract the secrets of herbs and roots and stones. Sometimes this curiosity has been repressed and not infrequently these natural philosophers have been charged with being in league with the devil, reviled as promoters of a black art, branded as heretics worthy of the dungeon and the stake. But from generation to generation, from century to century, at least a spark of this natural curiosity survived and from time to time it burst into flame and lighted pathways through the encircling gloom. And when the truth is known, it must be recorded as an outstanding characteristic of these inquisitive souls, these nature lovers, these men of science, that they labored from no selfish motive, sought only to know, pursued truth for its own sake, and gave freely to mankind what in patient and unremitting toil they garnered from the fields of investigation and research. Galileo, Newton, Priestley, Faraday, Maxwell, Tyndall, Liebig, Darwin, Agassiz, Pasteur, and others of their kind are names revered by every man of science, honored for the persistency with which they followed the gleam, the unselfishness with which they pursued the truth. Has this spirit continued down to our own day? Several years ago a foreign student entered the research laboratory of Ira Remsen and asked to be assigned a problem for investigation. A problem was assigned him and in the course of the research a compound was obtained which proved to have a remarkably sweet taste. The student soon took his departure and in a short time announcements appeared of his having secured patents in this and other countries covering the manufacture of saccharin. A legal friend remonstrated with Professor Remsen for not contesting the patentee's claim on the ground that he himself was entitled to the fruits of the discovery. But Professor Remsen's reply revealed the spirit of the older masters: "I am not pursuing investigations in chemistry for financial purposes but only with the hope of making some contribution towards the development of science."

Is this the spirit of the man of science of our own day? Or has the scientist also become possessed by the spirit of materialism? Are investigations now conceived and experimental data collected with patents in view? Is the research now prosecuted in feverish haste lest a rival worker be the first to reach the goal and secure the glory? Are men of talent now selling their brains and their scientific skill to captains of industry whose sole interest lies in the development of some new process, product, or method that will insure greater profits on invested capital? There are some who would answer these questions in the affirmative. It is well to remember, however, that it is neither in good taste nor a mark of sound wisdom for one to pass judgment upon the motives of others. It will probably be admitted that in these matters the university professor occupies a rather enviable position. Although his salary may not provide him with all the luxuries of the age, he is free to pursue his investigations along any line whatever that may give him the greatest satisfaction. In the choice of his field of labor he is the most independent man in the world and he is circumscribed only by the limitations of the resources the university may be able to provide. He is at liberty to seek truth for its own sake and he will find great satisfaction in giving to humanity the results of his investigations.

But it will be said that there is not a university professorship in reach of every man interested in science. Quite true, but there are the foundations established and endowed for the purpose of encouraging and promoting scientific research by the aid of liberal grants. Such institutions not only foster pure science but also, indirectly of course, lend encouragement to the conservation of this spirit of altruism. But there are not sufficient foundations to provide places for every one interested in the pursuit of science. Many, therefore, must turn to the doors of opportunity opened by industrial organizations. What is the atmosphere into which they enter and what is their reaction to these conditions? Is it purely a bread-and-butter proposition, a sort of earn-your-salary-or-get-out kind of a situation with research confined to strictly utilitarian ends? Or is there a reasonable degree of freedom with some encouragement for the solution of problems in pure science? Doubtless conditions will differ considerably in different organizations. It must be admitted that any corporation that can produce a Steinmetz, a Langmuir, a Coolidge, and a Whitney is making a larger contribution to the advancement of pure science than many a university. These men have apparently been free to blaze new trails and attack problems of a highly theoretical character and yet while they must be enrolled among the brilliant contributors to pure science, unquestionably they are also a tremendous asset to the corporation they are employed specifically to serve. Such a position for service may be regarded as a more ideal one than that of a university professorship.

But even granting that the research men in the laboratories of our industrial corporations must confine themselves largely to problems having a direct bearing on the practical applications of science, are they not in the end rendering a service to the general public, to humanity if you please, and not merely to themselves or to the stockholders of the corporation? Is it not possible that even these men are actuated by the spirit of altruism and that the fruits of their labors may rightfully be credited to the unselfish service of science?

A college youth of some eighteen or twenty summers heard his chemistry professor state that any one who would discover a practical way of obtaining aluminium in quantity would confer a benefit upon mankind and reap a fortune for himself. The youth resolved then and there to attack the problem and to stay with it until it was solved. He accomplished his purpose and accumulated a fortune. Professor Richards of Lehigh University is responsible for the statement that "one of the greatest metallurgical achievements of the nineteenth century was the addition of aluminium to the metals of every day life." The world is richer from Hall's process of extracting aluminium from the earth; need we attempt to weigh his motive in the moral balance?

A short time ago it was announced that a certain copper plated alloy of iron and nickel had been found to be a perfectly satisfactory substitute for platinum in making electrical connections through glass. This knowledge did not come over night but was the result of a long series of experiments suggested by certain principles of physical chemistry and carried out with a view to meeting an urgent practical need. Shall we convict the physical chemist of selfishness and greed, or commend him for a public service?

Recently there was successfully laid the twentieth transatlantic cable—the New York-London cable—but the event was not marked by the beating of drums or the blare of trumpets. And yet there is something quite distinctive about this cable for its copper core is wrapped with a tape of "permalloy," another alloy of iron and nickel, an alloy having thirty times the magnetic permeability of soft iron. This makes it possible for the copper core to carry messages eight times as fast as any other ocean cable. Now this remarkable alloy was not the product of a dream or the result of an accident but resulted from investigations carried on by the research engineers in the laboratories of the Western Electric Company. Admitting that these investigations were conceived and executed with a practical end in mind and that some corporation will receive considerable profit from the discovery, does not the benefit it confers upon the public far outweigh the profits to the company? Are we justified, therefore, in charging the research staff with the sale of their scientific skill for selfish aims? On the other hand, is it not another example of the debt of gratitude the world at large owes the man of science, and is the obligation less weighty because the scientist has endeavored to serve the world by the solution of a problem admittedly of a utilitarian character?

In a recent address before the American Chemical Society, Irénée du Pont made this statement: "In a case, the details of which are known to me personally, a company employed men for several years and finally brought out a new product which saved the public many millions of dollars. Out of each hundred dollars saved by the invention ninety seven dollars were passed to the public, two dollars and seventy cents were passed to the pioneer company, and thirty cents to the men doing the work in recognition of their success. This case is probably fairly representative, though the public believes that both the company and the men instrumental in bringing out the product have been most generously rewarded."

During the past two years your speaker has come in almost daily contact with a student who each morning injects into his arm a bit of insulin. This daily act stands constantly between this young man and death. Shall we in the name of pure science ascribe to Dr. Banting the glory of a great discovery and on the other hand charge with selfishness the corps of scientific workers in the pharmaceutical plant that has made insulin available to thousands?

Not infrequently it is deplored that so many men of conspicuous scientific ability are leaving university laboratories to accept positions in industrial plants, the implication being that they have forsaken an honorable career, the pursuit of science for its own sake, and bartered their knowledge and training and skill for a mess of pottage. To those who take this attitude towards the men of science in industry there will come some consolation from the observation that there appears to be a trend in the other direction since, during the past few months, five men of prominence in our own country have left industrial fields to accept university positions.

But after all has been said is not the accumulation of knowledge, the discovery of truth, only the first act in the great drama of human progress? Knowledge is of value only so far as it is put to practical use. It may be of considerable interest from a purely scientific point of view to know the life history of the typhoid bacillus but it is of far greater importance to apply that knowledge in preventing the occurrence and spread of typhoid fever. And here it might be said that since scientific discoveries may be utilized for either constructive or destructive purposes, the true man of science is he who takes no thought of the possible ultimate results of his discoveries but labors on with the sole purpose of finding the truth. 'Tis his to play the first act of the drama. The curtain falls and when it rises again, 'tis the man of applied science who occupies the center of the stage; and he may be hero or villain for dynamite may open roadways through mountain barriers or shatter cathedrals into dust.

But may we not revise the drama, reconstruct the play, and direct it towards a happier conclusion?

Sir Richard Gregory has well said: "When scientific work is instituted solely with the object of securing commercial gain, its correlative is selfishness; when it is confined to the path of narrow specialization, it leads to arrogance; and when its purpose is materialistic domination, without regard for the spiritual needs of humanity, it is a social danger and may become an excuse for learned barbarity."

For more than half a century the world had become increasingly impressed with the beneficent results of the development of science and then suddenly, without the slightest warning, it was given an appalling exhibition of the applications of science for purposes so destructive as to threaten the very foundations of civilization. Perhaps it was in contemplation of this colossal waste and destruction that President Angel was moved to state a fact and voice a prophecy in these words: "Strangely enough, the scientific mastery of the facts of man's own nature and the laws which control society linger far behind the corresponding insight into the nature of the processes of the physical world. But surely it is only a matter of time when these social sciences, so called, will also have perfected a technique enabling man to secure mastery over himself and his social relations comparable with that which has begun in the control of physical nature."

Is it sufficient for men of science to reply: "'Tis ours to discover the truths of physical nature; let others teach men wisdom and justice and beneficence in the application of her laws"? Shall we not rather expect of men whose ability to discover truths in the physical world has its very foundation in the spirit of truth within themselves, something more than a merely cold intellectual interest in natural phenomena? Shall we not expect of them such a spirit of humility, altruism, and self-sacrifice, born of this spirit of truth and expressed in the spirit of service, as will point the world to a better way of living? Has this not been true of the great men of science in the past, and shall it not be increasingly so with all men of science in the future?

It is to the *unselfish service of science* that we owe our present, still far from complete, control of natural forces, our increased span of human life, our comparative freedom from plague and pestilence, our agencies of relief in time of physical suffering, our means of rapid communication and intercourse, our agencies for the ready diffusion and dissemination of knowledge, and the material comforts and luxuries which soften the asperities and provide the adornments of human living. In all reverence I express the conviction that when the spirit of true science shall have become more completely infused into all races and all classes a great impetus will have been given to the coming of that day visioned by the great Teacher when he went forth "to preach the gospel to the poor, to heal the broken hearted, to preach deliverance to the captive, and recovery of sight to the blind, to set at liberty them that are bruised, and to preach the acceptable year of the Lord."

THE STATUS OF SCIENCE EDUCATION

JAMES F. MACKELL, INDIANA STATE NORMAL SCHOOL, TERRE HAUTE.

On every hand we hear the statement that we are living in a scientific age; that science means progress and that advances in science are far outdistancing human progress in other fields. From every quarter comes the demand that religion, politics and education move forward to meet the challenge set up by advances in the realm of science. Indeed it is no uncommon thing to hear theologians, statesmen and literary critics reminisce over the golden age of yesterday, but in the field of science no one doubts that tomorrow will dawn brighter than today. H. G. Wells, the historian, says: "When the intellectual history of this time comes to be written, nothing, I think, will stand out more strikingly than the empty gulf in quality between the superb and richly fruitful scientific investigations that are going on and the general thought of other educated sections of the community." While it is unlikely that thinkers in these other fields would care to acknowledge Wells as their authorized spokesman, yet it is quite probable that their own statements on the subject would be in a similar vein.

One would think therefore, that since science is the acknowledged leader in the field of human endeavor, science courses in our schools would outrival courses in other fields in popularity and in richness of content. It would certainly appear that in an age of automobiles, radio and super-power plants, physics courses would be crowded to the doors with eager searchers for truth; that in an age when advances in biological and medical research are adding every few years, an additional year to the expectancy of human life, we would be confronted with a tidal wave of students electing courses in these fields! Strange as it may seem this is not the case. The following figures (Table I) taken from the reports of the U. S. Commissioner of Education show the percentages of students in the various branches of science in the secondary schools of the United States over a period of 30 years.

TABLE I.—Percentage of High School Students Taking Science Courses

	1890	1895	1900	1905	1910	1915	1922
Physics	21	22	19	16	15	14	9
Chemistry	10	9	8	7	7	8	7
Botany	......	......	......	......	16	9	4
Zoology	......	......	......	......	8	3	2
Physiology	......	28	27	22	16	10	5
Physical Geography	......	22	23	21	19	15	4
Geology	......	6	4	3	1	.5	.3
Astronomy	......	5	3	2	1	.5	.1
Biology	......	......	......	......	......	7	9
General Science	......	......	......	......	......	......	18

"Proc. Ind. Acad. Sci., vol. 36, 1926 (1927)."

It will be noted that certain divisions of science have practically disappeared from the high school curriculum, while two new fields, namely general science and general biology are on the upgrade. Physics and Chemistry are still in the fight for existence. Geology, Physiology, Geography, Astronomy and Zoology are practically out of the race and even the old reliable Botany is about to give up the struggle.

Now it will be said by some people that this evolution is to be expected because of the general enrichment of the curriculum in recent years by the addition of the newer fields of Music, Art, Commerce and industrial subjects. Students have a wider field of electives and some of these newer subjects give greater promise of vocational value. It is worthy of note however, that in a similar study of the other fields of educational endeavor, no such striking decimation is apparent. Even the much abused Latin is holding an enviable place. Mathematics likewise is holding its "place in the sun", while English and the social sciences are making gains. If the newer fields are cutting in upon the older so-called academic lines, why is science their particular prey? Even if we take into account the increases in the fields of general biology and general science, yet there is a distinct falling off in the percentage of students in science when we compare the years 1895 and 1922. This is not true for the other academic lines. (See Table II).

TABLE II.—Percentage of High School Students Taking Courses Other than Science

	1890	1895	1900	1905	1910	1915	1922
German	11	13	15	20	24	24	.6
Latin	34	44	50	50	50	39	28
French	9	10	10	11	12	11	16
Rhetoric	......	29	34	40	52	30	......
English Literature	......	......	37	41	57	59	79
Algebra	43	52	55	56	57	49	40
Geometry	20	25	27	28	31	27	23
History	28	35	38	41	56	51	77
Music	......	......	......	......	......	32	25
Agriculture	......	......	......	......	5	7	5
Domestic Science	......	......	......	......	4	13	14
Manual Training	......	......	......	......	......	11	11
Book Keeping	......	......	......	......	......	3	11

Teachers of science quite frequently are led to declare that science courses have been put to an unfair disadvantage by school administrators and curriculum makers because science has been left quite generally in the elective field while English, History and some of the other academic lines have been kept in the required group. There may be some truth in this general statement but again we are confronted with the question, "Why are certain courses deemed of sufficient merit to warrant this discrimination?" It is unlikely that administrators will always and consistently ignore the popular demand. If certain courses are put in the required list, they are very likely there because of public opinion. Neither history nor mathematics would stay in the group of required subjects overnight if there was a popular demand in the other direction.

Thus it seems that we must search for the cause of our trouble in other channels. It might indeed, be fruitful if we teachers of science should make an inventory to see just what sort of science instruction we are measuring out to our students. The mere fact that scientific research is bearing fruit in vast abundance is no assurance that science education may be expected to advance without improvements in technique of teaching compatible with advances in subject matter. The average high school boy or girl who elects physics or botany may enter the class expecting to learn all about the thousands of phenomena of his every day existence, only to be disillusioned by a labyrinth of mathematical formulae, technical discussion and Latin names. He becomes lost in keeping up a notebook or a herbarium crammed full of abstract and medieval data. He loses sight of a physical phenomenon in the intricate and abstract mechanisms by means of which he is supposed to arrive at a scientific truth. He questions the teacher's right to have him waste his time in proving laws and deriving formulae. A chemical change turns out to be an algebraic equation, a beautiful flower becomes a botanical specimen with an unpronounceable name and his radio set becomes so entangled in mathematical formulae that he begins to wonder how the thing works at all. Dumb as he may seem to his teacher, the truth finally permeates into his thinking processes that he is not getting what he anticipated so he either quits in disgust or goes ahead listlessly only to be turned out in the end with little or no knowledge of the subject matter over which he has passed.

It seems strange indeed that in a field of subject matter which should lend itself naturally to the concrete, so much which is abstract and uninteresting can be conjured. The fault must lie with the teacher and with his teachers in the teacher training institutions from which he has received his training. A little of the right kind of training in science teaching most assuredly would lead a prospective teacher of science to the knowledge that university methods of instruction are not conducive to best results in high school science. If there really is such a thing as technique of teaching, and educators assure us that there is, it is not at all unlikely that a study of teaching methods might help matters. It certainly must be a fact that there is some way to present subject matter of a scientific nature which will appeal to the student and which will give results. At any rate it cannot be denied that in the main our present methods of science instruction are not attended with success. As an example of the failure of high school science instruction let us call to mind the results of a test given under the direction of Dr. A. L. Foley of Indiana University in 1922. This was a test to ascertain the college student's knowledge of high school physics. The test was participated in by 1058 students in beginning courses of college physics in several of the colleges of the state, including the State Normals. The questions were simple enough and were scattered over the field of high school physics. It is not likely that any high school physics teacher would consider the questions unfair. No high school physics course could have been imagined which did not emphasize every one of the points covered by the questions. The results obtained were startling, the grades ranging from 8.7 per cent for C. N. C. to 24.9 for Valparaiso. State Normal students averaged 21.9 per cent and Indiana 19.8 per cent. This test may not mean very much but it shows one thing and that is that some of the things which we expect high school students to get from a study of high school physics are not obtained. Surely there must be some way to get better results.

Of course it is an amusing pastime for college teachers to criticize high school work and for high school teachers in turn to criticize grade school teaching and so on down to the kindergarden, and it is only when the criticisms are supported by studies such as that made by Doctor Foley that we need take the trouble to heed them. In the December, 1925, number of School Science and Mathematics and in the November, 1925, number of School and Society, Dr. R. A. Millikan, head of the Norman Bridge Laboratory of California Institute of Technology, writes at some length upon the question of secondary science teaching. In this paper Doctor Millikan deals with several phases of the science teaching problem. One of the points which he stresses and the one in which I am particularly interested has to do with teacher training. He says in part that we have been spending too much time upon technique courses and not enough upon training teachers in subject matter. He says also that teachers' colleges are not training, and cannot by their very nature train science teachers. He furthermore states that the technique of science teaching has been fully developed and that it is merely incidental at best. In other words he challenges the teacher colleges' right to existence in so far as training high school science teachers is concerned.

Now I do not agree with Doctor Millikan at all on several points. If the technique of science teaching has been fully developed I have not heard about it. If any atmosphere is adapted to developing such a technique surely the teachers' college should have it, and not the great university. The very fact that such a technique has not been developed and put into successful practice does not speak well for our teachers' colleges for it is their business to do it. I am speaking primarily about science but I have no doubt that the training of teachers in other fields might admit of improvement. It has been my observation that a great number of university men are in accord with Doctor Millikan's ideas concerning teachers' colleges and we must not forget that their opinions have considerable weight in moulding public opinion against the ability and right of teachers' colleges to train high school teachers. There is no reason why teachers' colleges may not have faculties in science who are quite as well prepared, in so far as subject matter is concerned, to give instruction as do the great universities. As a matter of fact, a very considerable amount of the teaching of undergraduate science in the universities is carried on by instructors and assistants whose ground-work in the fundamentals of the subject matter is quite limited. Men like Millikan do little if any undergraduate teaching.

In my opinion, the teaching of science in college to students who are going to be engineers or enter the medical profession is quite a different problem from that of training high school teachers of science. Furthermore, if there is a technique of science teaching or indeed of any kind of teaching that technique must be specifically applied in the courses of instruction given college students to fit them for high school teaching. What I mean by this is that every course should be taught with the definite teacher training aim in view. The place to apply teaching technique is in the class room where science teaching in college is carried on. Teachers of high school science teach very much as they have been taught. If their college teacher knows something about the high school problem and teaches his course with that definite aim in view, the teachers so trained should be better able to interpret and understand the needs of high school students and to put the subject matter on a plane which will appeal to them. I do not mean by this that teacher training courses in science need be of a "wishy-washy" character or of an undignified nature. I cannot see why it need be in any way less collegiate or less dignified than pre-medic or pre-engineering science. In my opinion, the very fact that in the main, teachers of science in teachers' colleges have failed to recognize this aim constitutes one of the principal reasons why science instruction in high school has not been conductive to the best results. And while I believe that the same criticism applies to some extent to the other academic fields, yet the unique fact that the percentage of high school students taking science is falling off year by year indicates that in the other fields something is being done to attract students.

There is another phase of this situation which in all probability accounts for the falling off of high school students' interest in science and that is the very unsatisfactory high school science curriculum. Time does not permit, nor am I prepared to deal intelligently with this phase of the subject, but it seems to me that a revision of the science curriculum is imperative if we are to expect satisfactory results. But again this is a problem for teacher training institutions. There should be a science sequence developed, and the subject matter should be brought up to date. Motivation should be the keynote of all science teaching if we wish to make a lasting appeal to high school students. The subject matter of science is interesting enough and the present day need of scientific knowledge for everybody is unquestionable. The failure in my opinion lies in the fact that in the choice of subject matter and in the method of presentation of scientific instruction to high school students we have failed. I cannot bring myself to the thought that science is going to disappear from our high school curriculum. Something will be done by some agency to put it in its proper place. There is no agency better adapted to this task than the teachers' college.

TEACHING CONSERVATION IN INDIANA

SIDNEY R. ESTEN, Indiana State Department of Conservation.

Conservation is a word often misunderstood by the people of Indiana. Many think it means to horde—to save—as did old King Midas in days of old when each night by the dim candle light he counted over his pieces of gold. The time came when King Midas died, and as far as he was concerned his gold did him no good.

Conservation of our natural resources does not mean this. It means the wise use of our natural resources. For example, if one has a 20 acre woodland plot and builds a high fence around it, leaving it always as it is, he is conserving as King Midas did; but if he uses the woodland wisely, he takes out each year for use the mature timber to allow the younger trees an opportunity to get light and space in which to grow and come to maturity. He would eliminate undesirable species and propagate those which are desirable. Conservation today means the wise use of the resources we have, not for ourselves alone because we have all the trees, flowers, water, fish, animals, and birds we need for existence, but for the benefit of the many unborn citizens that will come after we are gone. If we conserve wisely, they may enjoy and use the natural resources and natural beauties, which should be the nation's heritage to them for the years which are to come. Consequently, the conservation program is one whose aims are far-reaching and worth while because it lives for the future.

Most people in Indiana today do not understand the meaning of conservation and are not using our resources to the best advantage. Under the able direction of Mr. Richard Lieber the Conservation Department of the State in co-operation with other departments in other states and the national government is endeavoring to put the great conservation program into effect. The department is divided into six divisions, each with its respective superintendent, as follows:

Land and Waters, Capt. Charles G. Sauers; Engineering, Mr. Denzil Doggett; Geology, Dr. William N. Logan; Entomology, Mr. Frank N. Wallace; Forestry, Mr. Charles C. Deam; Fish and Game, Mr. George N. Mannefeld.

The state legislature makes the conservation laws and the fish and game division provides game wardens to enforce them. However, the greatest need is for education of all the people in the state along conservation lines so that legislative enforcement may become less necessary. To this end Mr. Lieber and others of the department spend much time addressing various organizations over the state, but they have many other duties and cannot spend their entire time explaining conservation.

Therefore there is need of a man to spend full time over the state lecturing and explaining conservation to the people, especially where

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education does its greatest good, that is, to the young people of the state, the boys and girls in the schools, so that these future citizens may have an understanding of the needs of conservation when they take their places in our communities. This need had long been felt in the state, so during the latter part of the year 1924, arrangements were made between the National Association of Audubon Societies of New York and the Conservation Department of Indiana whereby Mr. Alden H. Hadley of Monrovia was employed to spend nine months of each year lecturing over the state on birds and conservation. Mr. Hadley's title was Field Worker on Birds and Conservation for the Division of Fish and Game of the Department of Conservation, and he worked in co-operation with the National Association of Audubon Societies.

Mr. Hadley, ex-state president of the Audubon Society and donor of the Hadley Collection of Bird Skins to Earlham College, began his work on January 10, 1925. He was furnished an especially equipped Ford roadster carrying a stereopticon lantern, 200 colored slides of birds belonging to the Conservation Department, and about 200 colored bird slides from photographs of his own, a large curtain screen with carrier attached to the side of the car, literature on conservation and junior Audubon work, and charts and books on nature study.

His duty was not only to speak to children in the schools but to speak on problems of conservation to any and all groups of adults, including civic clubs, farmers, sportsmen, parent-teacher's groups, and women's clubs. Mr. Hadley continued this work until March 1, 1926, when his resignation took effect that he might become assistant to Dr. T. G. Pearson of the National Association of Audubon Societies in New York City.

The success of the work in the state was assured by the work of Mr. Hadley who had paved the way, organized the work, outlined the policies, and acquainted the people of the state with the conservation idea. Thus when the Conservation Commission appointed as his successor, Mr. Sidney R. Esten, of Indiana University, requests for lectures over the state were on hand to keep him busy for two months. Requests for lectures are constantly coming in and a program for at least two months in advance is easily made. A translux daylight screen and many new slides have been added to the equipment.

The following lectures are now available or will be available by September 1, 1927:

No. 1. A lecture on birds for first to fifth grade children. This lecture is in story form, modeled after Thornton W. Burgess's bird book for children. 35 slides.

No. 2. A lecture on birds for sixth to eighth grade children introducing, in addition to the birds, insects, frogs, and snakes. 50 slides.

No. 3. A lecture on conservation for high school students and adults. This deals with forestry, trees, streams, fish, water pollution, animals, flowers, insects, and birds. 65 slides.

For adults the following lectures are available:

No. 4. A general lecture on bird study and value of same. 83 slides.

No. 5. Uncommon and interesting birds. 51 slides.

No. 6. Bird Nests and Bird Protection. 79 slides.

No. 7. Economic Ornithology. 80 slides.

No. 8. Shore and Game birds. 40 slides.

No. 9. Hunting and fishing, especially adapted for fish and game clubs and Isaac Walton Leagues. 60 slides.

No. 10 and 11. The Mountains of our Northwest and Conservation in the State of Washington. 110 slides.

No. 12 and 13. Trees and Forestry problems. 120 slides.

No. 14. Insects. 80 slides.

No. 15. Flowers. 60 slides.

No. 16. State Parks. 60 slides.

A summary of the work from January 10, 1925, to December 1, 1926, by Mr. Hadley and Mr. Esten is as follows:

1.	Grade School Groups	522	talks	to	101,378	people
2.	High School Groups	88	"	"	24,883	"
3.	Normal School Groups	10	"	"	1,575	"
4.	College Groups	13	"	"	2,900	"
5.	Junior Girl Groups (Campfire, Girl Scouts, etc.)	6	"	"	240	"
6.	Boy Scouts	5	"	"	475	"
7.	Civic organizations	22	"	"	1,400	"
8.	Woman's Club Groups	10	"	"	960	"
9.	Parent Teacher Groups	15	"	"	3,197	"
10.	Teachers Groups	5	"	"	380	"
11.	General adult groups	9	"	"	1,195	"
12.	Bird and Nature Groups	19	"	"	1,385	"
13.	Sportsmen Groups	10	"	"	1,200	"

The complete summary shows that in the 17 months of actual work in the field, 760 lectures averaging 40 to 50 minutes each have been delivered to 140,980 people. The total number of speaking hours was 570, the average number of talks a month was 45, and the average number of people spoken to each month was 8,281. The average number of people hearing each talk was 180 and the smallest group spoken to was 15 at a small district school in Dubois County. The largest groups spoken to at one time were groups of 1,200 each at the Crawfordsville High School and at the South Side High School of Fort Wayne.

One of the main features of the work among the grade children from the first to eighth grades, Boy Scouts, Girl Scouts, Camp Fire Girls, and nature groups is the organization of Junior Audubon clubs.

The record of Indiana's progress in the increased interest in bird study of the boys and girls of the State as shown by Junior Audubon membership is as follows:

		June 1, 1924	June 1, 1925	June 1, 1926
1st	New York	56,015	44,518	45,949
2nd	Pennsylvania	42,776	39,875	38,798
3rd	Ohio	26,581	20,428	26,670
4th	Indiana		16,083	22,337
5th	Massachusetts			21,532

Junior Audubon membership means that the boy or girl has joined a group and has received six pamphlets, each pamphlet telling of a different kind of bird and each containing a colored picture and one uncolored picture for coloring of each of the six kinds of birds. The boy or girl also wears a club button, a different kind being issued each year. When a group exceeds 25 in number it is called a club and the teacher gets for that club a year's subscription to "Bird Lore." Junior Audubon membership is emphasized to the child as standing for three things: Bird interests, organized bird study, organized bird protection.

Thus the conservation idea is being planted in the hearts of the boys and girls that they, as they grow older, may become conservationists of the future and teachers of conservation to future generations. That which begins by education in a small way today will be felt by millions of future citizens of our nation. With adults various phases are taken up according to the desires or needs of the group.

During the 17 months of the work, about 21,000 miles have been covered over many parts of the state, a distance more than equivalent to three transcontinental trips from New York to San Francisco and back.

It is amazing to note the increased interest shown throughout Indiana by men and women in various walks of life whose work and interests would appear to carry them far away from nature. Deep within them is a keen sense of the beautiful things in nature and an enthusiasm for nature study which makes them eager to hear of the flowers, trees, insects, animals, and birds.

The systematic teaching of conservation in Indiana by a field lecturer is only in its infancy, but the experiences and results shown by the past two years bid fair for greater and more far reaching effects and influence in the years which are to come.

NOTE ON THE SO-CALLED "SYNTHETIC AQUA MARINE."

FRANK B. WADE, Shortridge High School, Indianapolis

As is well known, there have been on the market for some years artificial sapphires of various colors, notably blue, red (ruby), pink, white, golden, hyacinth red, and one type which is bluish green by bright daylight but amethystine by artificial light.

All the above artificial precious stones have been found to have essentially the properties and composition of sapphire. Recently there have appeared stones of a light blue tint which have been offered and sold under the name of "Hope aqua marines." The properties of this new stone have been studied by the author and they will be listed and discussed in this note.

A rough boule of the new "aqua marine" procured from L. Heller & Sons of New York was found to have two well developed crystal faces. This is unusual, as most of the boules of artificial sapphire are anhedral. On measuring the angle between these two faces it was found to be the same, within the limits of error of the method, as that between the octahedral faces of a cleavage octahedron of fluorite. This led at once to the conclusion that we probably had to deal with a material that crystallizes in the cubic system rather than in the hexagonal. True aqua marine is beryl, which crystallizes in the hexagonal system.

On testing the optical properties of the synthetic "aqua marine" it was found to be singly refracting, and without dichroism, as would be expected of a crystal in the cubic system. Its hardness proved to be greater than that of natural aqua marine but less than that of sapphire. Its specific gravity was greater than that of beryl but less than that of sapphire. The refractive index also lay between the indices of sapphire and of beryl.

Suspecting from its properties that the new material was artificial spinel, more accurate determinations of several of the properties were made. The specific gravity, refractive index, hardness on Mohs' scale and angle between crystal faces were all found to agree with those of natural spinel. It was therefore concluded that the material might more properly be called a light blue artificial spinel than an "aqua marine."

It may be said that the new artificial stone is a worthy material in every way. It is really better in nearly every respect than natural aqua marine since it is harder, of higher refractive index (and consequently capable of being cut to produce greater brilliancy) and of better color than most natural aqua marine. The prices asked for it too are very reasonable and it may be had in adequate size for almost any purpose. It is not sold as a natural material so there is no fraud. It might however be better to sell it under the name of synthetic spinel, although commercially that would involve educating the buying public in regard to a little known gem.

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SOME FEATURES OF THE CINCINNATI ARCH AS SHOWN BY GEOLOGICAL CONDITIONS IN AN INDIANA GAS FIELD.

WILLIAM N. LOGAN, INDIANA UNIVERSITY.

The eastern Indiana oil and gas producing area, locally known as the "Trenton field", is located chiefly on the sides and partly on the top of the northwestern extension of the Cincinnati arch. The conformation of the arch has been a matter of considerable speculation. Conceivably the arch may be a single simple fold with a fairly uniform structural outline. On the other hand it is possible to conceive its being a geanticline with many minor undulations or structural irregularities. Both of these views have been expressed but apparently the simple fold has found greater favor.

Difficulties in the solution of the problem arise from several sources. A study of bed-rock strata has been impossible because of glacial covering. In the study of the meagre evidence from sub-surface records there appeared an uncertainty as to the presence or absence of major unconformities and of later differential movements. In the presence of accurate logs from closely spaced wells, the solution of the problem would not have been difficult.

It is evident that in the case of a simple fold containing a sand of uniform thickness and degree of porosity the gas, oil, and water will be arranged according to their specific gravities. Departures from this order of arrangement may be assigned to irregularities in structural conditions, such as are present in a geanticline, to lack of water pressure, or to variations in the porosity of the petroliferous sand. In a general way the distribution of gas and oil in the Trenton field indicates gravity control in a simple fold. However, there are irregularities of distribution and these have been assigned commonly to differences of porosity. An alternative hypothesis will be presented in this discussion.

Information regarding sub-surface conditions has been obtained by the writer from a number of localities. One of these areas is located partly in Howard and partly in Tipton counties. Through the kindness of the Indiana Natural Gas and Oil Company the logs of a large number of wells distributed through the area were obtained for study. It was found that the close spacing of the wells in certain parts of the area made it possible to make certain deductions regarding structural conditions. The following discussion applies to the area selected for study.

Location. The area lies in the northern part of Tipton County and in the southern part of Howard County between Kokomo and Tipton. The city of Sharpsville is near the center of the area. The size of the area is about 153 square miles.

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Topography. The surface of the region is that of a very level plain. The maximum difference in relief is 95 feet. The highest surface elevation is 917 feet above sea level. This point is located in the southwestern part of the area in Section 8, T 21 N, R 3 E. The lowest point is about three miles southeast of Kokomo in Section 16, T 23 N, R 4 E. The elevation is 822 feet above sea level. The slope between these points is a gradual one.

Since the area as a whole lies within the Tipton till plain it is probable that at the close of the late Wisconsin glacial stage the surface was practically level and that the relief which it has at present has been developed by post-glacial erosion. The surface topography bears little relation to structural conditions. The greater part of the highest relief is over synclinal areas though the highest point lies above an anticlinal area.

Stratigraphical conditions. The Pleistocene and Recent deposits occupy the surface of the area. They consist of sands, gravels, clays and loams. The maximum thickness of the drift is 287 feet and the minimum is 35 feet. The drift includes both Illinoian and Wisconsin drift materials. The Pleistocene deposits rest on the eroded surface of rocks of Silurian age. Preglacial erosion has deeply trenched the surface of the Silurian but the deposition of the drift filled up the depressions in the surface.

Silurian rocks. Only the upper part of the Silurian rocks are exposed at any point in the general area. In the area under discussion they are not exposed. According to well records they consist of shales and limestones which, in the vicinity of Kokomo, have a total thickness of 360 feet. From the log of the Wm. Moore well in the vicinity of Kokomo in Center Township the following Silurian section was obtained:

Silurian Section From Moore Well.

Limestone, thin bedded	10 feet.
Limestone, bluish, more massive	80 feet.
Limestone, white, shaly	95 feet.
Limestone, bluish	65 feet.
Shale, calcareous	35 feet.
Limestone, gray	75 feet.
Total	360 feet.

Ordovician rocks. The Silurian rocks rest upon the surface of the rocks of the Cincinnatian group of the Ordovician system. The rocks of the Cincinnatian group consist of thin bedded limestones and shales. The total thickness of the group in the Moore well referred to above is 511 feet.

STRUCTURAL FEATURES.

In making a study of the structural conditions two key horizons were used. The first from the surface was the basal contact of the Silurian limestone with the shale of the Cincinnatian group. The highest structural point obtained by using this horizon is 444 feet and the lowest 301 feet above sea, giving a range of 143 feet between highest and lowest structural points. The highest productive point is 431 feet above sea and the lowest 312 feet above sea. The range in altitude of productive area is 119 feet on the structures. The amount of structural height above productive area is only 13 feet.

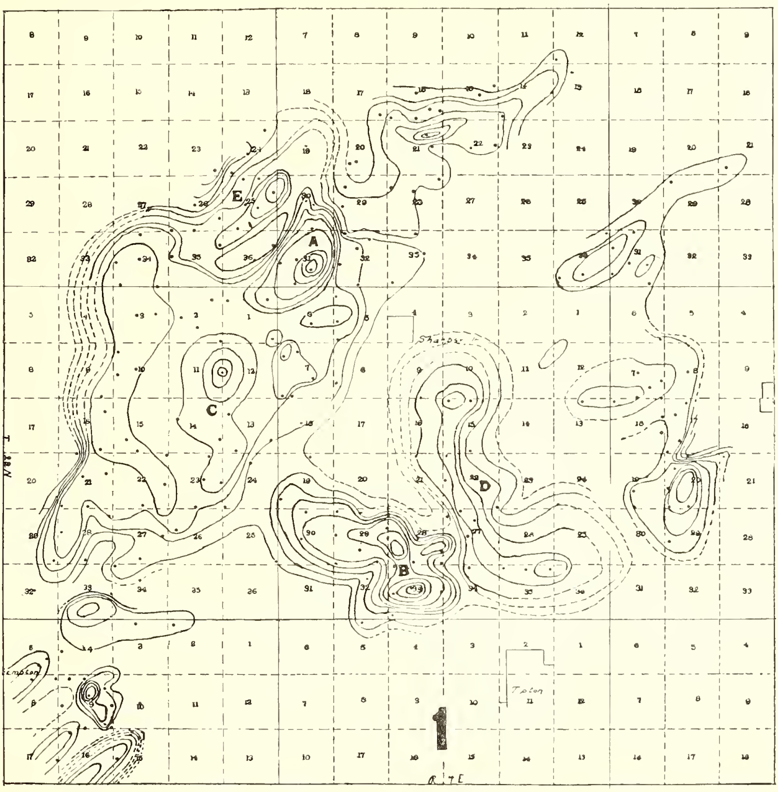

Fig. 1. Showing irregularities developed on the surface of the Cincinnatian shales by using the Silurian-Ordovician contact as a key horizon. The contour interval used is 20 feet.

Trenton key horizon. Using the contact between the Cincinnatian group and the Mohawkian (Trenton) limestone as a key horizon the highest productive point is 61 feet below sea and the highest non-productive point 68 feet below sea. The lowest productive point is 14 feet below sea. The range in altitude of productive area is 79 feet as compared with 119 feet on the upper key horizon. The difference in elevation between production and non-production on the structure is seven feet on the higher parts of the structures and only three feet on the lower parts of the structures.

STRUCTURES.

The highest structures in the area are included in the following list:

Structure A—located in Sections 30, 31, 32, mainly, in R 4 E, T 23 N.

Structure B—located in Sections 28, 29, 32, 33, mainly, in R 4 E, T 22 N.

Structure C—located in Sections 11, 12, 13, 14, mainly, in R 3 E, T 22 N.

Structure D—located in Sections 10, 15, 22, 27, 35, R 4 E, T 22 N.

Structure E—located in Sections 25, 30, mainly, in R 3 E, and R 4 E, T 23 N.

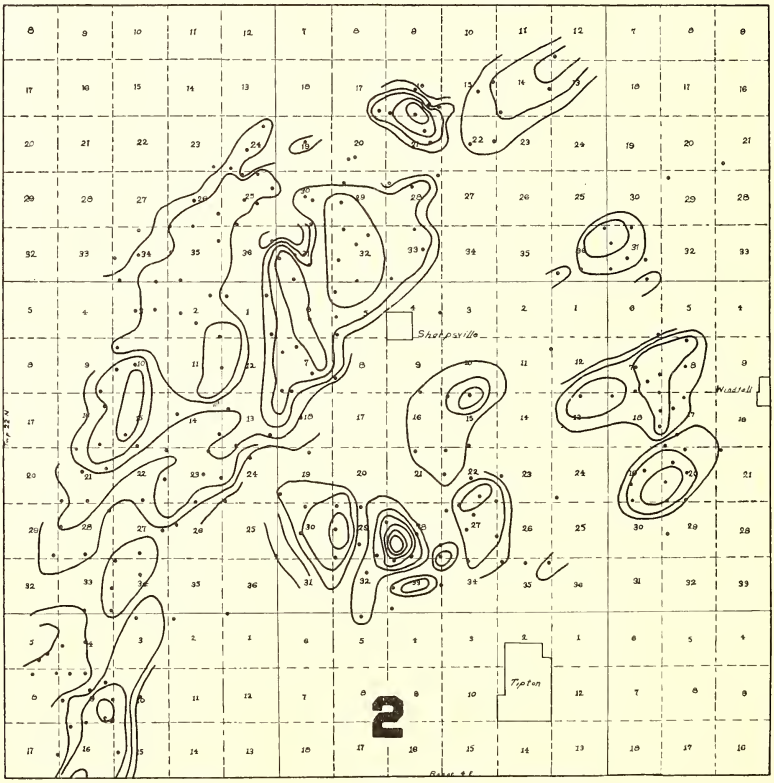

Fig. 2. Showing irregularities developed on the surface of the Mohawkian (Trenton) limestone of Ordovician Age. The key horizon used is the top of the Trenton limestone. The contour interval is 10 feet.

Structure A. On Structure A production was obtained at elevations (using the first key horizon) between 350 and 408 feet above sea. Above and below these limits, so far as our records go, there was no production. On the structure within these limits there were found five producing wells and two non-producing. Non-producing is not used in the sense that no gas was found but with the meaning that no commercial quantities were obtained. Structure A covers a little more than one square mile of surface.

Structure B. This is a compound structure consisting of three parts. The highest part reaches an elevation of 431 feet above sea, another part attains a height of 421 feet and a third of 405 feet above sea. The surface of the structure between these high points is slightly lower. The main part of the structure occupies an area of about two square miles. Production was obtained from an altitude of 370 to 431 feet on the structure. There were ten producing wells and four non-producing.

Structure C. This is a simple somewhat elongate structure, the highest point of which is 410 feet above sea level. The main part of the structure occupies about one square mile of surface. Production was obtained between 382 and 410 feet above sea. Within these limits were found five wells of commercial importance and four that were not.

Structure D. This is a compound structure consisting of two high points both of the same altitude. They are separated by an horizontal distance of three and one-half miles. They are joined by a ridge the upper surface of which is about 20 feet lower than the high points. More closely spaced wells on this structure might reveal other points of equal or greater height than those at the extremities of the ridge. The productive area on this structure extends from 384 to 401 feet above sea. The number of productive wells between these limits was ten and the non-productive wells was four in number.

Structure E. This is a simple structure occupying about one square mile of surface. Its highest point is about 388 feet above sea. Production was obtained between 354 and 388 feet above sea on the structure. There were eight producing and no non-producing wells on the structure.

Other Structures. There are 12 other structures within the territory covered by the well records. These structures are partly or wholly outlined. They show no marked differences from those described.

Possible Causes of Irregularities. The irregularities of the surface of the Cincinnatian shales might be accounted for on the basis of structural conditions only. It would seem however if they were formed by folding that they should be less pronounced than those on the surface of the Trenton but the reverse is true. It might be suggested that these irregularities were due in part to sub-aerial erosion. However, the trenching which is so generally present in the sub-aerial erosion of soft rocks is apparently not present. Another suggestion which might be made is that the high points are due in part to sub-aqueous erosion. If erosion of any type is responsible it would seem that sub-aqueous erosion best conforms to the conditions of the irregularity produced. The mud-lump type of origin may be objected to on the ground that in a general way the high points on the higher horizon correspond to those on the lower.

It is probable that when the Cincinnati arch in the region of Cincinnati was brought above the sea the northwestern extension across Indiana was defined as a sub-aqueous ridge. Assuming that this be true it is conceivable that the surface of this ridge had the general irregularities as to outline as those existing on the surface of the Trenton limestone. It is apparent that this ridge did not reach the surface of the water since there is no evidence of sub-aerial erosion in the region under discussion.

Assuming that the folding was Post-Silurian then an incompetent bed would be folded between two competent beds. It would seem to the writer that under those circumstances the folds which would be produced in the incompetent layer would be regular in outline. The structures developed on the Cincinnatian shales are not of this type as has been explained in previous pages.

Gravitational compaction may have had an influence in producing the irregularities if it be assumed that the ridges on the rocks below the shales were developed, prior to their deposition, either by folding or by erosion.

THE SILURIAN CORAL REEFS OF NORTHERN INDIANA AND THEIR ASSOCIATED STRATA.

E. R. Cumings and R. R. Shrock, Indiana University.

The Silurian (Niagaran) rocks of northern Indiana are characterized at numerous localities by unusual dips, indicating cone, dome or quaquaversal structures. The origin of these peculiar structures with their highly inclined beds has long been a matter of controversy. Associated with these structures is a definite stratigraphic sequence, consisting of a number of distinct lithologic units.

It is the purpose of the present paper to present evidence that these structures are ancient coral reefs; and to propose names for the various units of the associated stratigraphic sequence.

Summary of the Literature.

The earliest mention of these structures was by Richard Owen (1862, 98), but no theory was advanced to explain their origin. Collett (1872, 307) accounted for the high dips at Delphi by "profound cross-bedding"; but said of the quarry near Kentland (1883, 59), where dips as high as 90 degrees are present: "This quarry is a mystery". Gorby (1886, 228-241) suggested a narrow anticline extending across the State, to which he gave the name "Wabash Arch". In this proposal he was heartily seconded by Maurice Thompson (1889, 41-53; 1892, 177-186), who emphatically stated that Gorby's conclusions were absolutely correct.

Phinney (1891, 653) was the first geologist to study the structures in detail. He presented evidence against Gorby's hypothetical "Wabash Arch", and suggested for the first time the coral reef theory of their origin. Later Elrod and Benedict (1892, 200-238; 1894, 22) spoke of the dome-like structures in Wabash County, calling the rock composing them "Picket Rock", and accounting for the high dips as a variety of cleavage, simulating stratification planes. Ashley and Siebenthal (1899, 190) mentioned high dips in the vicinity of Kentland and attributed them to "volcanic or other agencies" which "had produced an upheaval of a kind seldom found in nature".

These high dips at Kentland, sometimes as much as 90 degrees, are due to faulting and associated crumpling, as outcrops now visible clearly show, and are not related in origin to the dome-like structures found elsewhere in the northern part of the state.

Elrod (1902, 207) in discussing the unconformities in the Niagaran rocks of Indiana, mentioned a number of high dips in several northern counties; but said nothing of their origin. Blatchley (1904, 229, 235, 237) mentioned high dips as due to true upheaval, and quoted L. C. Ward, who had stated that the dips at Huntington pointed to "a greatly complicated set of folds or faults, or both". Kindle (1902, 221-224; 1903,

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459-468; 1904, 411) suggested that the structures may be analogous in origin to the mud-lumps of the Mississippi Delta. Ward (1906, 216) realized the complexity of the high dips near Kentland, stating: "It is a synclinal fold, much broken in the folding". That there has been faulting at Kentland is now perfectly clear. Cumings (1922, 449) considered these high dips, especially at Kentland, where the Ordovician is brought to view, as genuinely vulcanic or disastrophic in origin, and suggested the possibility that cryptovolcanic action might be responsible for the dome-like structures.

THE ASSOCIATED STRATIGRAPHIC SEQUENCE.

Associated with the dome-like structures of northern Indiana, and in part contemporaneous with them, is a series of strata consisting of five lithologic units or formations.

Mississinewa shale. The basal formation of this mass is a drab to bluish-gray, calcareous shale. It outcrops in the west part of Huntington, just west of the tourist camp; at a number of points along the Wabash River from Huntington to Lagro; in the vicinity of Lagro at the base of the Hanging Rock; at the south end of the bridge over the Salamonie River just west of Hanging Rock; at the Narrows upstream a short distance from the outcrop just mentioned; northeast along the Wabash Railroad; southwest along the Wabash River, and along Lagro Creek; one and one-half miles northwest of Warren along the Salamonie River; at a number of places between Lagro and Wabash; along the small stream in the tourist camp and city park in the west part of Wabash; on the flanks of the "Wabash Dome"; in the deep road cut on the south side of the river and along the river bluff in South Wabash; along the Mississinewa River at Marion, Jalapa, Mt. Vernon, Somerset, Maple Grove, Morgan's Cliff and Red Bridge; along Liston Creek in Wabash County; at low water level in the Wabash River opposite the mouth of Little Pipe Creek, one mile west of Peru; at the base of the Kokomo limestone in the Markland Avenue quarry in Kokomo; in quarries one mile east of Yorktown along White River; at Alexandria and vicinity; and in a quarry in the bank of White River one-half mile west of Anderson.

To this formation from the base of the yellow limestone above, downward as far as typical development continues, is given the name *Mississinewa Shale,* from the Mississinewa River, along which it is well exposed and typically developed at or near river level at the localities mentioned above.

Owing to its slight dip, no one exposure shows both the top and the bottom of the formation. In fact the true base of the formation has never been seen by the writers. The greatest observed thickness is at Wabash, where 75 feet are exposed. Here it outcrops on the south side of the river in the bed of the stream, some 300 feet downstream from the bridge on Wabash Street, and is found in the bluff, 75 feet above the river. Outcrops elsewhere show from one to 50 feet. Elrod and Benedict, on the basis of well logs, reported 114 feet at Lagro; and stated that the formation is probably as much as 250 feet thick.

The Mississinewa shale includes the "thick-bedded argillaceous limestone" and "hydraulic limestone" of Collett (1872, 326) and the equivalent formations: the "laminated shale," "cement rock," and probably the "hydraulic limestone" of Elrod and Benedict (1892, 197, 201-203), who gave an excellent description of the way the formation weathers, and also described its lithologic characteristics. It is unlikely, however, that they ever realized the true relations of the formation to the dome-like structures.

Below are given four chemical analyses of samples of this formation from widely separated localities.

	Yorktown	Somerset	Wabash	Lagro
Loss on ignition	26.38	29.81	25.44	26.70
Silica	30.28	30.60	30.89	31.06
Alumina	14.07	16.72	13.21	12.16
Ferric oxide	5.80	2.48	5.69	3.02
Titanium oxide	0.73	....	0.68	0.64
Lime (CaO)	15.90	14.34	15.70	17.16
Magnesia	5.72	6.05	6.82	8.85
	98.88	100.00	98.43	99.59

The striking homogeneity of the formation is shown by comparing the above analyses. They show little more than four and one-half per cent difference in any one constituent. This fact is significant when one notes that Yorktown and Lagro are more than 50 miles apart. It is very probable that this marked homogeneity is characteristic of the shale over its entire outcrop area.

A second fact to be noted is the high percentage of argillaceous material, alumina (Al_2O_3), ferric oxide (Fe_2O_3), and silica (SiO_2). Since the argillaceous material constitutes 50 per cent or more of the samples, it is seen that the formation is a calcareous shale or argillaceous limestone (calcilutyte). In view of the fact that the formation, when weathered, splits into laminae like a typical shale, and has no sharp bedding planes and joints, it is deemed best to speak of it as a calcareous shale rather than as an argillaceous limestone.

In fresh outcrops the formation appears very massive; but on weathering it changes from bluish-gray to drab or buff in color, and breaks up into large irregular blocks with conchoidal fracture, and finally into thin slabs and flakes characteristic of weathered shale.

In the quarries near Yorktown a Graptolite (*Dictyonema*) fauna is found associated with Brachiopods, Gastropods, Trilobites and Cephalopods. Strap-like markings, probably plant remains, are also quite abundant. Specimens of Graptolites have also been found at Wabash in the shale on the flanks of the Wabash Dome and in the deep road cut south of the river; along the Mississinewa River near Double Cliffs; in the shale at the base of the Kokomo limestone in the Markland Avenue quarry in Kokomo, where they are associated with abundant specimens of

Atrypa reticularis and other common Niagaran fossils; and at Markle, where they occur in great abundance in a formation that greatly resembles the Mississinewa shale, but has not yet been identified with certainty.

Red Bridge Limestone. Lying above the Mississinewa shale is a bed of reddish-yellow colored, impure, argillaceous limestone, varying from six inches to six feet in thickness. It outcrops one mile west of Huntington, along Little River; in a ravine one-half mile east of Lagro; along the bluff in South Wabash; along the Mississinewa River at Mt. Vernon, Somerset, Maple Grove, and Red Bridge; and along Liston Creek in southwestern Wabash County, where it is responsible for the Liston creek falls.

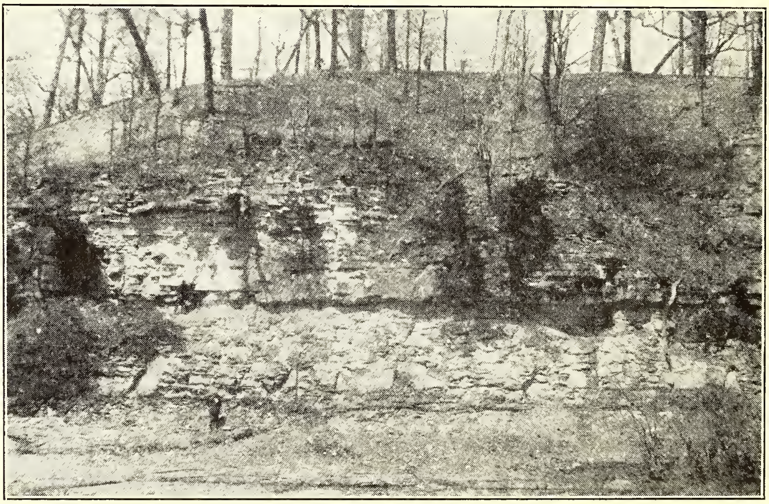

Fig. 1. View of the Red Bridge section. The lower shaly formation is the Mississinewa shale. The massive five-foot bed is the Red Bridge limestone, which is in turn overlain by the Liston Creek limestone.

To this bed is given the name *Red Bridge Limestone,* from the village of Red Bridge on the Mississinewa River in southwestern Wabash County, where it is well exposed in a high bluff on the north bank of the river west of the bridge. In this excellent outcrop both the underlying and overlying formations are beautifully exposed, as shown in figure 1. The Red Bridge limestone at the type section is from three to five feet thick. Its normal thickness is about two feet.

The formation is lithologically different from both the underlying and overlying formations. Its color also is distinctive. Weathering changes the color from reddish-yellow to yellow, and reduces the bed to a fine sand or silt. It is very persistent in its lithologic characteristics and thickness throughout its outcrop area, and is always found between the underlying Mississinewa shale and the overlying cherty limestone. For this reason it forms an excellent key horizon and is very useful in structural determinations.

As yet no fossils have been found in this formation, although careful search has been made at several localities. It is very doubtful if either Collett or Elrod and Benedict recognized this horizon, since no mention is made of it in their reports.

Liston Creek Limestone. Lying above the Red Bridge limestone is a series of thin slabby limestone beds, with considerable associated chert. This formation is seen outcropping in a ravine one-half mile northeast of Lagro; along Charley Creek in the west part of Wabash; along the bluff in South Wabash; one-half mile west of Rich Valley in an abandoned quarry; along the Mississinewa River at Mt. Vernon, Somerset, Maple Grove, Morgan's Cliff, Red Bridge, and Seven Pillars or "The Cliffs"; and along Liston Creek.

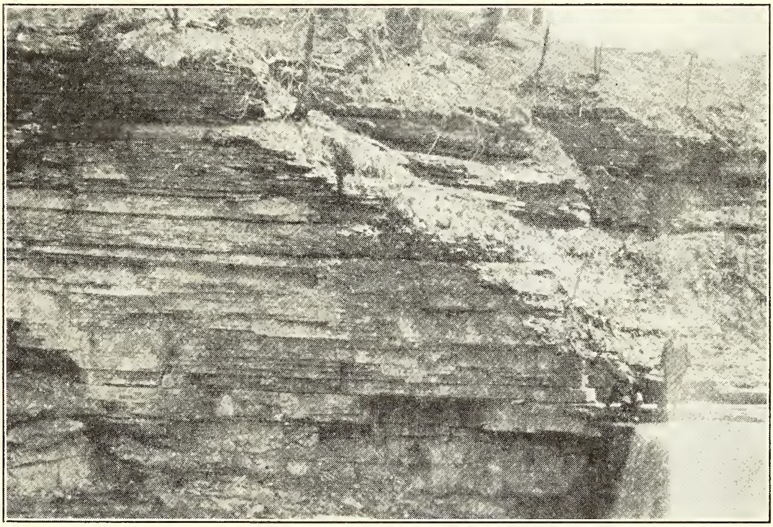

Fig. 2. View of Liston Creek Falls. The water is flowing over the Red Bridge limestone. The shaly formation under the falls is the Mississinewa shale. The Liston Creek limestone overlies the Red Bridge limestone and is 26 feet thick.

To this cherty formation, 26 feet thick in the type section, is given the name *Liston Creek Limestone*, from Liston Creek in southwestern Wabash County, along which are well developed outcrops. Only a portion of the formation can be seen in any of the sections. Its top is unknown. Its relation to underlying strata is shown in figure 2.

The lower portion of the formation is slabby and contains less chert than the upper part. In the upper part there are often thin layers or beds of chert, which seldom exceed four inches in thickness. Chert nodules are also present in the thin limestone layers.

Fossils are found sparingly throughout the entire formation; and there is a thin zone near the middle which contains large numbers of Bryozoa.

This formation has been used throughout Wabash and Miami counties in the region of its outcrop, for road material. Good exposures are often found in abandoned quarries; for example, in South Wabash; one-half mile west of Rich Valley; and along the Mississinewa River. Quarrying is never carried deeper than the Red Bridge limestone, for the latter is useless for road material. Therefore in all abandoned quarries, from which the Liston Creek limestone has been taken, the Red Bridge limestone will be found to form the floor of the quarry.

The Liston Creek limestone is the equivalent of the "paving stone" of Collett (1872, 326) and the upper part of the "quarry stone" or the "Wabash Flagging" of Elrod and Benedict (1892, 197).

In a few outcrops a druzy brown or yellow very fossiliferous dolomite is associated with the Liston Creek. The exact position of this formation is not certain. It may represent an overlying formation distinct from the Liston Creek, or it may be only a local development of it, found only adjacent to the coral reefs. This brown formation is found in South Wabash, one-eighth of a mile east of the deep road cut, in an abandoned quarry; in an abandoned quarry north of Mt. Vernon on the north bank of the Mississinewa River; and about a mile upstream from Peoria along the south bluff of the Mississinewa River. Each of these exposures is near the flank of a coral reef, and it is likely that the prolific fauna found in the formations represents the inhabitants of the waters near the reef. Further work will be necessary before the exact status of the formation can be determined.

The Kokomo Limestone. Unconformably overlapping the Niagaran sequence above described is the Kokomo limestone of Foerste (1904, 33), which is probably of Cayugan Age. This formation consists of 60 feet of finely laminated impure limestone, more argillaceous in the lower portion and more calcareous in the upper portion. Alternate beds of earthy material and purer limestone are characteristic.

This formation is exposed in several quarries in Kokomo, one on Defenbaugh Street, and one on West Markland Avenue, the last being the best exposure in Kokomo at the present time; in two abandoned quarries a mile southwest of Kokomo; one mile west of Peru opposite the mouth of Little Pipe Creek, where it unconformably overlies the Mississinewa shale; one and one-half miles west of Peru along the newly excavated drainage canal; along several small streams west of Peru, on the south side of the Wabash; in the lime quarry three miles east of Logansport; at Kenneth on the Pennsylvania Railroad, six miles west of Logansport, where it is beautifully exposed in an active quarry; at Big Blue Hole Quarry, now abandoned, three miles west of Logansport; and in the south bank of the Wabash opposite Kenneth. Its characteristics have been noted elsewhere and need not be repeated here.

The Kenneth Limestone. Resting upon the Kokomo limestone is a very cherty limestone formation from one to 20 feet thick in the outcrops. The base of this formation is exposed in the Defenbaugh and Markland Avenue quarries in Kokomo. Greater thicknesses are seen in the Big Blue Hole and Kenneth quarries, and in the vicinity of the latter place.

This formation is appropriately called the *Kenneth Limestone*, from the fine exposures in the great quarries at Kenneth Station, and in other outcrops in the immediate vicinity. The top of the formation is not known. Kenneth Station is selected as the type locality because the quarries and other outcrops are in the upland well above drainage, and can never be totally obscured by water, as is now the case with the type section of the Noblesville.

Certain peculiar structural relations of this cherty limestone and the underlying Kokomo, seen in the Markland Avenue quarry at Kokomo, indicate the possibility of an unconformity between the two. Further work will be required, however, to determine this point.

It will be noted that in the preceding discussion no definite thickness has been assigned several of the formations. The reason is obvious. The formations occur in a deeply drift-covered region of little relief, where outcrops are few, and usually along the beds or low banks of streams, or in shallow quarries. There is also very little dip to the main sequence above described. Occasionally the coral reefs, because of their greater resistance to erosion, give rise to structural hills, on the flanks of which may occur small outcrops of the stratified beds. Few outcrops show both the bottom and the top of a formation. In fact only the Red Bridge and the Kokomo formations have been seen in their entirety in any one outcrop. Of the other formations only the top or the bottom has been seen. It is obvious, therefore, that in naming these formations it was necessary to select a place where as much as possible of the typically developed formation was present, and also where there was a minimum likelihood that the outcrop would ever be obscured.

Finally attention should be called to the fact that no mention has been made of Kindle's Noblesville and Huntington formations (1904, 407-408). The type section of the Noblesville is now almost completely hidden by the water of the new city reservoir on the river above Noblesville; and it is very difficult to get hold of enough material to indicate what the significant lithologic characteristics and fauna of this formation are. The Huntington formations are in a similar situation since the old quarries at the type locality are nearly full of water and the rock can be seen only around the edge. The fate of these two type sections should be a warning to geologists to select type sections with a view to the future. Work now in progress will ultimately indicate the validity and stratigraphic position of these two formations. For the present it seems best to regard them as phases of the reef rock next to be described.

THE CORAL REEFS.

As promised in the introduction, evidence will now be presented indicating that the dome-like structures found in northern Indiana are fossil coral reefs. These structures will therefore, in the balance of this paper be spoken of as *reefs*.

General characteristics. These reefs are in general dome-shaped masses of calcareous material having a massive unstratified core composed partly of the remains of Stromatoporoids, corals, Bryozoa and other reef-building organisms, and thickly set with small irregular pockets of calcite. A distinctive fauna characterizes the reefs. This central core will hereafter be spoken of as the *reef proper* or *core*.

Adjacent to this central unstratified mass or core, are found well stratified thick beds of dolomite leaning against the core at high angles, but changing to lower dips as they extend away from the core toward the periphery of the reef-dome, and finally assuming a horizontal position and interfingering with or intergrading into the surrounding sediments of the normal stratigraphic sequence. The latter represents the deposits of the level sea-bottom of the inter-reef areas. Its chief representative is the Mississinewa shale, already described.

The reef proper or core. The reef proper is the central unstratified mass against which the inclined strata were deposited, and represents the direct constructive work of the reef building organisms. In the reefs open to observation in northern Indiana the exposed part of the reef proper is never over 45 feet in height, and seldom exceeds 300 feet in diameter. Since, however, neither the true top nor base of any reef has been seen, the total height of the reefs is not known. It is certain that the true height is much greater than the figure stated above.

The rock composing the reef proper is a hard, gray to pink, ragged, porous dolomite, containing many pockets of calcite, and in some cases numerous poorly preserved Stromatoporoids, corals and other fossils. It is very resistant to erosion, so that the reefs often form structural hills, such as may be seen at many points along the Wabash River. It breaks into jagged splintery pieces. This rock has been called "Picket Rock" by the people of the region. (See Elrod and Benedict, 1892, 197.)

Calcite occurs in abundance both in cavities or pockets, along the slickensided surfaces (joints and fault planes), and in fault breccias. Where it occurs in pockets it probably represents original vacuities in the reef or occupies cavities produced by the destructive solution of fossils, especially corals. The fossils of the core are nearly always very poorly preserved and often quite unidentifiable.

Slickensides constantly characterize the reef proper. The slickensided surfaces are often inclined at very high angles, 45 to 65 degrees, and may cause the center of the core to present the appearance of great cones set one over the other. It is probable that many of these slickensided surfaces represent joints and faults rather than bedding planes. Stylolites are abundantly developed along the slickensided surfaces and bedding planes, and as mentioned by Stockdale (1921, 54), extend vertically, and not normal to the surface on which they are found. These stylolites are, therefore, due to intraformational solution under the static pressure of the overlying rock, and were obviously formed after the solidification of the rock. Stylolites are especially well developed in the west end of the quarry one-eighth of a mile east of the deep road cut in South Wabash.

Typical exposures of the reef proper may be seen at the locality just mentioned; in the "Wabash Dome" at Wabash; at Georgetown; west of Logansport; and in the south bank of the Wabash River at Lockport.

The inclined beds surrounding the reef proper. Dipping sharply away from the core are highly inclined stratified beds of yellowish-gray to pinkish limestone and dolomite, which as they extend outward, thin rapidly, forming wedge-shaped masses that interfinger with the members of the normal stratigraphic sequence already described. These dips, being in all directions from the more or less cylindrical core, give rise to a quaquaversal structure, presenting the false appearance of upheaval.

The angle of dip of these beds varies from four or five degrees at the outer margin or periphery of the structure to as much as 65 degrees where they join the core. It is such extraordinarily high dips that have proved a stumbling block to nearly all investigators who have tried to explain the structures.

For example, Elrod and Benedict (1892, 222) say: "Compound bedding, conformation to irregular surfaces, and unequal shrinkage, either alone or in combination, are sufficient to explain the variations of the dip in true stratification, but fail to account for the phenomena where it exceeds twenty-five degrees. Some theory must be applied to the rocks in which a high angle dip is the most obvious feature." Kindle (1904, 404-405) states: "A serious objection to the coral reef theory is the frequent absence or scarcity of corals where the dips are the heaviest. Corals are not at all abundant in the Niagaran of this region. They have not been observed anywhere in sufficient abundance to form reefs. While inequalities in the sea bottom may be responsible for some of the smaller undulations in the strata, neither they nor 'offshoots of the Cincinnati Arch' appear to offer a satisfactory explanation of dips from 45 degrees to 75 degrees in the Niagara beds which the accompanying photographs show." One of these photographs referred to shows nearly vertical strata near Kentland. As already explained it is not germane to the present discussion.

Twenhofel (1926, 433, 526-528) says that the highest initial dip material may have, due to the angle of repose, is 41 degrees; but further states that the initial dip may be subsequently steepened by settling or slumping. One dip of 54 degrees, in the Shoonmaker quarry, near Wauwatosa, Wisconsin, is mentioned. (See also Grabau, 1903, 342). Grabau (1901, 176) describes and figures a coral reef near Alpena, Michigan, and says: "The strata dip away from the reef in all directions. At first the angle is 28 degrees, then it falls to 14 degrees, and then to 4 degrees, and finally to 2 degrees, the normal dip of the strata in the quarry." This structure could be closely duplicated in northern Indiana. Grabau (1903, 338-342) further mentions dips of from 30 to 40 degrees in the Alpena limestone of Michigan, and quotes Chamberlin, who mentioned: "The increase in thickness of the sedimentary layers toward the reef with which they finally merge". Grabau says: "Of forty-one slopes determined on the Bahama Islands, the lowest is 0 degrees, the highest 26 degrees 18 minutes. Seventy-five per cent of the slopes are below 10 degrees, while one-third of the entire number of determined slopes fall below 5 degrees."

"On the Keeling Islands on the other hand, only a few slopes below

10 degrees are recorded by Dietrich. Nearly half of the number lie between 30 and 43 degrees, one being as high as 63 degrees 21 minutes."

It is clear from the preceding quotations that slopes of 30 to 45 degrees are not uncommon on coral reefs, and that slopes as high as 63 degrees have actually been observed. High dips are, therefore, to be expected, rather than the contrary.

The paucity or absence of corals in these structures is not to be taken too seriously, since the greater part of many modern reefs often consists of the contributions of organisms other than corals, especially lime-secreting algae. In the Indiana reefs Stromatoporoids appear to have made the chief contribution, and their dolomitized remains are often extremely abundant in the reef core. In a few cases, as at Georgetown, Bluffton, and South Wabash, corals are common; but not abundant. Some of the abundant calcite has probably replaced some of the corals and other organisms. In the slightly inclined strata near the periphery of the reef, corals are often extremely abundant and very well preserved, as is the case at Bluffton and Huntington.

Slickensides are usually well developed in these inclined beds near the core, and occur along bedding planes, and probably along joints also. They are probably due to the downward slipping of the beds upon one another because of the great weight of superincumbent strata that once undoubtedly covered the entire region, but have long since been eroded away.

Faults are frequently found in the inclined beds. One of the best examples is in the abandoned quarry at Wallick's Mill, one and one-half miles southwest of Peru, along Little Pipe Creek, just below the railroad bridge. Here a well developed fault breccia can be traced for a distance of 75 feet. Minor faults are given off at right angles to the main fracture. The movement seems to have been chiefly vertical.

In the large quarry south of the railroad switches in the northeastern part of Huntington, the evidence points to a slight vertical displacement in the east end of the quarry, in beds dipping about 25 degrees.

Within 250 feet of the reef core the inclined beds usually flatten out and interfinger or merge with the members of the normal stratigraphic sequence. This interfingering is a very characteristic feature of reefs, and is mentioned by Grabau, Twenhofel, and other students of such structures. The formation most commonly seen in this relationship is the Mississinewa shale, which flanks most of the reefs. At South Wabash the Red Bridge and Liston Creek limestones are also represented. At Georgetown the horizontal beds of the Kokomo-Kenneth sequence approach the reef in an apparently unconformable relationship, although there is a possibility that here the reef continued into Cayugan time.

How far down into the Mississinewa formation the reef structure extends is not known, since nowhere is the base of a reef exposed. The relations of the reefs to this formation are best shown at Wabash; but may also be studied at Huntington; near Mt. Vernon and Double Cliffs on the Mississinewa; at Hanging Rock near Lagro; and one-half mile east of Yorktown on White River.

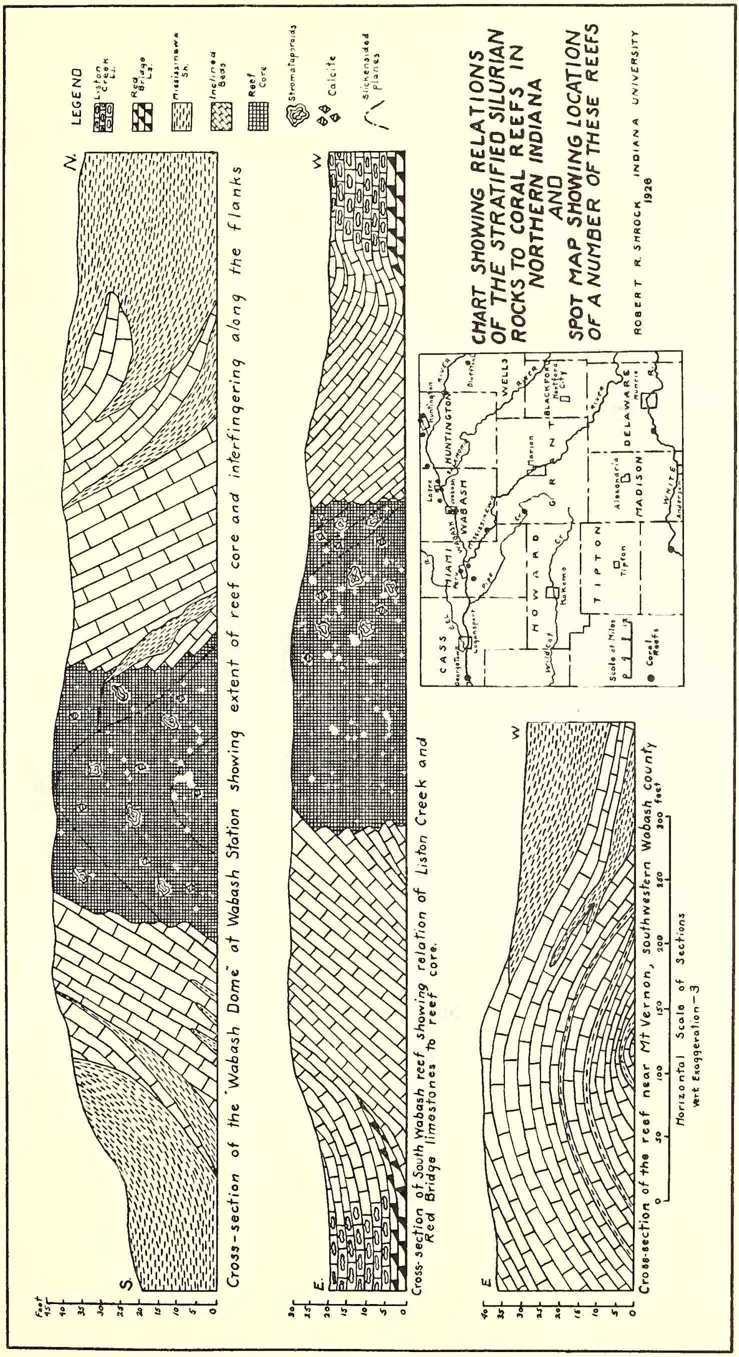
CHART SHOWING RELATIONS OF THE STRATIFIED SILURIAN ROCKS TO CORAL REEFS IN NORTHERN INDIANA AND SPOT MAP SHOWING LOCATION OF A NUMBER OF THESE REEFS
ROBERT R. SHROCK INDIANA UNIVERSITY 1926
LEGEND
Liston Creek Ls.
Red Bridge Ls.
Mississinewa Sh.
Inclined Beds
Reef Core
Stromatoporoids
Calcite
Slickensided planes
Cross-section of the 'Wabash Dome' at Wabash Station showing extent of reef core and interfingering along the flanks
S.
N.
Feet 45 40 35 30 25 20 15 10 5 0
Cross-section of South Wabash reef showing relation of Liston Creek and Red Bridge limestones to reef core.
E.
W.
30 25 20 15 10 5 0
Cross-section of the reef near Mt Vernon, southwestern Wabash county
E
W
40 35 30 25 20 15 10 5 0
Horizontal Scale of Sections
0 50 100 150 200 250 300 feet
Vert Exaggeration - 3
CASS
MIAMI
WABASH
HUNTINGTON
WELLS
HOWARD
GRANT
BLACKFORD
TIPTON
MADISON
DELAWARE
Georgetown
Logansport
Peru
Wabash
Lagro
Huntington
Bluffton
Marion
Hartford City
Kokomo
Tipton
Alexandria
Muncie
Anderson
Eel R.
Wabash River
Mississinewa
Wildcat Cr.
White R.
Scale of Miles 0 4 8 12
Coral Reefs

Fig. 3. Chart showing relations of the stratified Silurian rocks to coral reefs in northern Indiana, and spot map showing location of a number of these reefs.

DESCRIPTION OF CHARACTERISTIC REEFS.

The Wabash Reef. It now remains to describe in some detail several of the more typical reefs. (Fig. 3.)

In the railroad cut at Wabash station is a classic section cutting exactly through the center of one of these reefs, along a north-south axis. The isolated spur of rock east of the tracks aids in constructing a corresponding east-west section; and reveals an abundance of the Stromatoporoids that built the reef.

As revealed in the section (fig. 3), the exposed part of the reef core is some 250 feet long, and not over 40 feet high. Considerable calcite is present, and slickensides are common. There is no indication of definite bedding planes in the core; but the slickensided surfaces show dips as high as 65 degrees. These slickensided surfaces dip to the west, north and south on the west wall of the cut, and east, north and south on the east wall, thus giving rise to a cone-like structure.

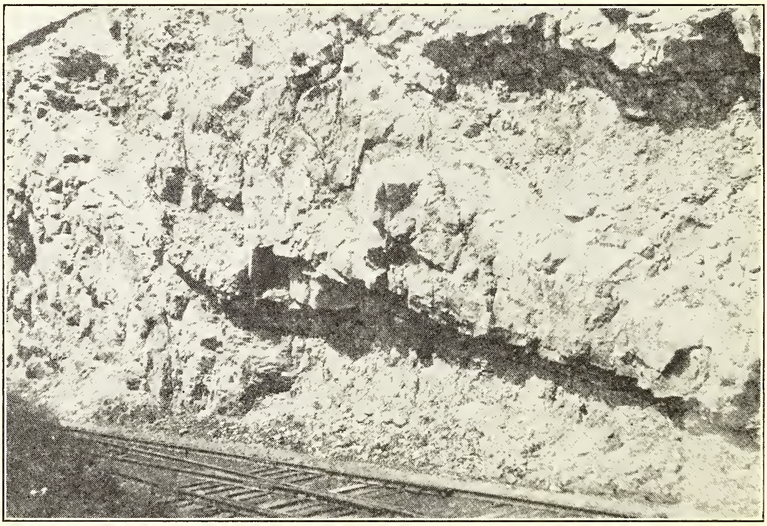

Fig. 4. View of the north flank of the "Wabash Dome" showing the interfingering of the Mississinewa shale and the inclined beds. Note the thickening of the limestone lens toward the core of the reef, to the left.

The inclined beds, near the core, vary from three to six feet or more in thickness, and dip at angles of from 12 to 65 degrees. The rock is a pink-tinted gray dolomite, containing a few fossils and small pockets of calcite. The beds dip from 30 to 50 degrees, ordinarily, near the core, but quickly flatten out to angles of from 12 to 18 degrees and finally become practically horizontal. Dips of 55 degrees were measured on the east wall of the cut, and one as high as 65 degrees was measured on a small lens of shale on the back of the spur that forms the east side of the cut. This is the highest dip observed anywhere in northern Indiana, outside of Kentland; and therefore represents the maximum for the true reef structures.

Small shale lenses are present in the south flank of the reef, and are even present in the core. The north flank shows the interfingering of the shale and the reef rock, particularly well, and is one of the most instructive exhibits in the state. The dip at this point is 30 degrees. The accompanying photograph (fig. 4) shows this interfingering very clearly. Just beyond the zone of interfingering, the shale is horizontal, and continues thus for half a mile north along the railroad, in its normal stratigraphic position. It is perfectly evident that the Mississinewa shale is contemporaneous with the reef, and that the latter was being built while the calcareous mud of the shale was being deposited in the adjoining waters.

The South Wabash Reef. This reef is located in South Wabash, across the river from the structure just described, and one-eighth mile east of a deep road cut in the Mississinewa shale. Although it is not as well exposed as the Wabash reef, nevertheless its structure can be fairly well determined from outcrops in a number of small quarries along the brow of the hill.

The reef proper is about 275 feet in diameter, but is exposed to a depth of less than 30 feet. While the Wabash reef is associated with the upper part of the Mississinewa shale, this reef, or at least its exposed portion, is associated with the Red Bridge and Liston Creek limestones.

In the west part of an active quarry that exposes the core of the reef many Stromatoporoids and some corals, very poorly preserved, are found, associated with much calcite. The latter occurs both in pockets and in connection with slickensides. The slickensided surfaces are inclined 45 to 50 degrees. The rock in the reef core resembles in all respects the rock of the reef previously described. On the west flank of the reef, however, where the inclined beds begin, the rock changes to a pinkish crinoidal limestone of rather crystalline texture. It has the characteristics of a coral breccia.

The inclined beds dip away from the reef core at angles varying from 50 degrees to zero, where they join the normal sequence. The Red Bridge and Liston Creek limestones appear to grade laterally into the inclined beds, with a transition in lithologic characters. At this point, on the west flank of the reef, a structural irregularity is present. The Red Bridge and Liston Creek beds lie horizontal, but the adjacent inclined beds dip at first downward *toward* the core at an angle of about 10 degrees, through a horizontal distance of 50 feet, and then gradually change to a dip of 15 degrees *away* from the core. Interwedging of the strata is conspicuous where this change of dip takes place.

Here also a yellow, very fossiliferous bed is present at the top of the exposure. Trilobites, Branchiopods and Bryozoa are very abundant. This rock probably represents a local development of the Liston Creek limestone, adjacent to the flank of the reef.

The Mississinewa shale outcrops near the reef on both the east and west sides; and it is likely that, were exposures available, the same relations of the shale to the reef would be seen as are found in the Wabash reef.

The Mt. Vernon Reef. At the old dam site on the Mississinewa River a mile north of Mt. Vernon and one-eighth mile above the bridge, the north flank of the well-defined reef is exposed. The outcrop is on the south side of the river where a small stream enters. As shown in figure 3, the section is tangential to the reef, and to one side of the core. The reef proper, therefore, is not exposed in the river bluff. Along the small stream the northward dip steepens, and it is probable that the core of the reef lies 300 feet south of the bluff. The Mississinewa shale is exposed along the west end of the bluff, interfingering in the usual fashion with the inclined beds, which here have rather low dips. Near the center of the outcrop the shale beds are observed to arch over the reef with the inclined beds.

This section shows just what would be expected if a section were taken along a chord near the outer limit of one of the reefs already described.

SUMMARY AND CONCLUSIONS.

It has been shown in the foregoing discussion that there is a definite stratigraphic sequence, consisting of distinct lithologic units, associated with the dome-like structures of the Silurian rocks of northern Indiana. The members of this sequence are named and described.

Strong evidence is presented indicating that the dome-like structures are coral reefs formed in the Silurian Sea. The massive, unstratified reef core, with its Stromatoporoids and corals, calcite pockets and slickensides and stylolites; the inclined strata, steeply dipping near the core, but rapidly changing to horizontality at the periphery of the structure, and interfingering with the members of the normal stratigraphic sequence; and finally the normal sequence itself, everywhere nearly horizontal and containing a fauna distinct from that of the core, all point to this conclusion.

Many puzzling structures, such as Hanging Rock, Morgan's Cliff, the outcrops at Wallick's Mill, Double Cliffs, and many others, inexplicable on any other basis, are easily and simply explained by the coral reef hypothesis. Such extensive structures as those of Huntington and Noblesville, and possibly Delphi, seemingly so complicated, may easily be explained as large composite reefs.

These reefs were contemporaneous with probably the entire Mississinewa shale, the Red Bridge and Liston Creek limestones, and possibly even with the Kokomo-Kenneth sequence. That they existed throughout Niagaran time is practically certain, and it is possible that some of them extended into Cayugan time.

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NOTES ON THE PRESENT STATUS OF WATERWAY DEVELOPMENT IN THE UNITED STATES.

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From the time the first Virginia Colony dropped anchor in the James River in 1607 to the present day, the use of the waterways of America has been a problem of greater or less prominence. Oddly enough, in the early history of our country, the advisability of attempted improvements of the inland waterways was much doubted. Benjamin Franklin, writing from Europe in 1772 concerning the experiences of the engineers in the Old World in their attempts to harness the streams, said, "Rivers are ungovernable things" and further stated that "the English engineers seldom use a river if it can be avoided."[1] This may have been the echo to an ancient Spanish decree to the effect that "since God has not made the rivers of Spain navigable, it is sacrilegious for man to attempt to do so."

All along the Atlantic seaboard a storm of ridicule and criticism was hurled at the men who advanced ideas and plans for the improvement of the waterways. It formed the topics for the cartoonist and "funny page" writers of the time. However, in the face of the ridicule a number of companies were formed and proceeded to carry out various plans of waterway improvement. Among these were, "The Potomac Company", 1785; "The Society for the Promotion of Navigation", 1791; and "The Western Inland Lock and Navigation Company", 1792.

The success of the Erie Canal in 1825 turned the tide in favor of waterway improvement and ushered in the period of great extension of inland waterway utilization, especially the construction of canals. Since 1825 waterway improvement has been accepted as an avowed policy of our government, and has been given almost universal approval by the American people. President Coolidge in his first two messages to congress advocated "The fullest possible development of our waterways." As it was unpopular in the early days to advocate stream improvement, so has it now become unpopular to even question the advisability of such work. Vast sums are appropriated by congress at each session for river and harbor improvements, for example, the amount expended in 1924 for such improvements amounted to over $62,000,000.00.[2]

Of the estimated 25,000 miles of navigable waters in the United States, exclusive of the Great Lakes, the Mississippi proper contains 1,944 miles, the Missouri 2,285 miles, and the Ohio 968 miles. These streams with their tributaries have received the greater attention and large sums have been appropriated for their improvement.

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[1] The Paths of Inland Commerce, A. B. Hulbert, pp. 30-31. Yale University Press, 1920.

[2] Ann. Rept. Chief of Eng. U. S. Army, 1924, pp. 3-5. Government Printing Office, Washington, D. C.

"Proc. Ind. Acad. Sci., vol. 36, 1926 (1927)."

The Ohio River Project. The Ohio River has an unusually favorable location. Its source is in the center of a great industrial district, some of its tributaries feed from the largest coal-producing fields of the United States, its east-west extension is in the direction of the movement of the great mass of American trade, and its mouth, nearly a thousand miles from its source, is in the heart of a wealthy agricultural region. These seem to be sufficient reasons for the undertaking of a gigantic project of improvement. The project is designed to furnish a continuous channel of nine feet depth at low water from Cairo, Illinois, to Pittsburgh, by the construction of 50 movable dams with locks. The original project called for 54 dams, but by adjustments of height and slightly shifting of positions of some of them it seems now that 50 or 51 will be adequate.

The status of the project on October 1, 1926, as reported by the Chief Engineer of the Central Division, Cincinnati, was as follows: 42 dams were completed,[3] and dam No. 45 was 95 per cent complete. Numbers 46, 47, and 49 were between 60 and 70 per cent complete; numbers 50 and 52 were 45 per cent, number 51 was 37 per cent, and number 53 was 35 per cent complete. The slogan is "On to Cairo by 1929."

Cost of the Project. The amount expended on new work to the end of the fiscal year 1924 was $76,631,576.[4] The estimated cost of the project when finished is $103,059,130. This does not include the cost of improving the channel, operating dredge and snag boats, nor the cost of annual maintenance. The latter estimate made in 1906 was $810,000 annually, which in 1926 would probably be three times that amount. The cost of operating snag and dredge boats annually for the past 100 years (1827-1924) has been $110,000. To this should be added interest on the sums invested and a sinking fund to provide for the return to the government of the principal sum. Computing this on the basis of the estimates of the cost of the completed improvements, together with 4 per cent interest on the investment as it accumulates during the 25-year period of construction, and providing for the retirement of the principal sum in 50 equal annual installments, together with the annual cost of upkeep would require an annual payment of about $7,500,000 for 50 years, or after completion, to 1980 A. D.

Traffic on the Ohio River. The tonnage hauled on the Ohio River as given in the annual reports of the Chief of Engineers of the U. S. Army 1919-1924, show a general increase, but with a larger tonnage for 1920 than for any other year previous to 1924, when the tonnage hauled was 10,866,683 short tons. This was double the tonnage hauled in 1919. The traffic for 1925 was reported to the writer by the Division Chief of Engineers of the Central Division as 15,737,015 tons and for the first nine months of 1926 as 13,604,353 tons, estimating the total tonnage for this year at about 18,000,000 tons. All of these data seem to indicate a marked increase in traffic with the extension of the improved sections of the river. The data, however, should be closely scrutinized before drawing conclusions as to the value of the project.

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[3] Dams 1 and 2 have been replaced by the Emsworth Dam, No. 42 has been abandoned, No. 41 at Louisville is being rebuilt and no work has been started on No. 54.

[4] Ann. Rept. Chief of Eng. U. S. Army, 1924, pp. 1210-1229.

Of the 8,000,000 tons of freight in 1923, only a little over 6,000,000 tons passed through the locks. The rest used the open channel, and at least that amount would have used the river if no improvements had been made. Three classes of traffic, i. e., coal, sand and gravel, and iron and steel goods make up 90.3 per cent of the upstream traffic, and 95.8 per cent of the downstream traffic. Of the downstream traffic, coal alone made up 88 per cent with an average haul of 59.8 miles. In the up-stream traffic, on the other hand, sand and gravel composed 54 per cent with an average haul of 9.8 miles.[5]

Much of the apparent increase of traffic of 1925 over that of 1924 is due to a change in the method of collecting data. Three of the five million tons increase included sand and gravel taken from the bottom of the river in the dredging operations and was not hauled out of the pool in which it was dredged. This item, not included in previous reports, can hardly be included in the statistics of commercial benefits of the improvements. An increase of shipment of over a million tons of coal and coke is, however, worthy of note.[6]

The average tonnage hauled on the river 1919-1923 was about 12,000,000 tons. As has been noted, nearly all of it has been coal and sand and gravel, and the average haul through the locks was about 50 miles. About one-fourth of the total traffic was through channel and open river, not using the locks, and presumably not dependent on the improvements made. The total cost as previously calculated (the payment of $7,500,000 per year for 50 years) would pay the freight by rail on 9,000,000 tons of coal for a distance of 52 miles. In other words, the actual cost to the government of the improvements of the Ohio River is sufficient to pay the freight on the average amount of traffic through the locks for the five-year period, and would continue to pay the railway freight rate on that amount for 50 years. Yet the government furnishes the improvements for the transportation companies and does not receive one cent in return for the use of the stream, nor for the use of the locks. What business institution could survive by such methods? If the government is recompensed, it must be by indirect results.

While waterway improvements may have many other beneficial results, as the storage of storm waters to reduce floods or to furnish water power, it should be noted that the improvements of the Ohio River are in the form of movable dams for aid to navigation. The dams are lowered during high water and during the winter time, and are used only during low water conditions of the summer, and are of no aid to either flood prevention nor to water power development. If the project has justification, it must be found in its benefits to navigation.

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[5] Com. Statistics of Rept. of Chief of Eng. U. S. Army 1924, pp. 1016-1020.

[5] Blue print data furnished by Division Chief of Eng. Central Division, not yet published.

Improvement of the Tributaries of the Ohio River. During the period of improvement of the Ohio River, most of its tributaries were undergoing improvement also. The chief tributaries on which a series of dams have been built, the number of dams, the miles of navigable waters provided, the cost of the construction of dams and locks, and the tonnage for the year 1923 is given in table I. While the dams on the Monongahela River are all in operation, it will be necessary to rebuild a number of them which were originally built by the Monongahela Navigation Company and will involve an additional expenditure of $5,875,000. The average tonnage 1916-1923 was about 18,400,000 tons, three-fourths of which was coal.

The Allegheny River project involves the construction of eight dams and the removal or elevation of seven bridges in Pittsburgh. The latter is being rapidly pushed forward. This project when completed will give a navigable depth for 61 miles. More than one-half the tonnage moved during 1923 was sand and gravel.

TABLE I. The improved tributaries of the Ohio River showing for each stream the number of dams constructed, the number of miles navigable above the mouth of the stream, the cost of the improvements to June 30, 1924, and the tonnage hauled during the year 1923. (Annual Report of the Chief of the Engineers, U. S. Army, to the Secretary of War, 1924, Government Printing Office, Washington, D. C., 1924.)

RIVER	Number Dams	Miles Navigable	Cost	Tonnage 1923
Monongahela	14	130	$8,940,000	23,560,000
Allegheny	5	29	3,500,000	4,612,640
Muskingum	11	91	2,988,000	214,261
Little Kanawha	5	48	631,918	98,088
Kanawha	10	90	7,063,300	1,572,821
Big Sandy	7	50	1,649,000	22,000
Kentucky	14	248	4,175,000	167,000
Green	7	196	3,478,500	338,000
Rough-Green	2	71	145,141	531
Wabash	1	91	260,000	87
Cumberland	15	318	13,737,000	413,000

Effects of Improvements on Freight Rates. One of the strong arguments for the investment of large sums on waterway improvement is that it is more than compensated for in reduced freight rates. The freight rates on five of the tributaries of the Ohio (Chief of Engineer's Report for 1924) is given in table II, and a comparison is made with the freight rates by rail for the same commodities. A study of the table shows that for these rivers, the average per ton mile rate for eight commodities on the five rivers was 74 per cent higher than the rate by rail between Bloomington, Indiana, and Indianapolis. The government has spent $28,500,000.00 to make these streams usable, but with the result that the shippers must pay even higher rates than those who have no waterways. It appears that the investment, at least on small streams, is an unadvisable expenditure of the Nation's money.

The decrease in river transportation from the hey-day of steamboat traffic on the Mississippi and Ohio to almost nothing, is explained by many as being due to the winding course of the streams, the silting of their channel, unfair competition of the railroads, and other causes. While the removal of the forests, continued cultivation of the land, and other causes may have resulted in a slightly increased silting of the channels, the truth is that streams have essentially the same characteristics today they had when steamboat traffic was at its height. The steamboat supplanted other means of travel because it was the fastest, most commodious, and cheapest means of transportation then available. When other means of travel with similar advantages over the steamboat were introduced, the importance of the steamboat correspondingly declined. Today, with steam and electric railways, and excellent highways for automotive traffic competing with the river transportation, it is difficult to see how the investment of any sum, however large, can greatly increase river shipments. River traffic must be confined to commodities of large bulk, great weight, and small value per bulk, in which time is a minor element in their movement. Even the shipment of these must be sought through the inducement of cheaper freight rates. Can these rates be made cheap enough, and the traffic great enough to justify the expenditure of so many millions of dollars?

TABLE II.—Showing the freight rates per ton mile of nine commodities on five of the tributaries of the Ohio River, with averages for each river and for each commodity; also the railway rates for the same commodities between Indianapolis and Bloomington, Indiana. (Annual Report of the Chief of Engineers of the U. S. Army—Commercial Statistics compiled by the Statistical Division, 1924. U. S. Government Printing Office, Washington, D. C.) Railway rates quoted by Illinois Central Freight Agent, Bloomington, Ind.

Commodity	Muskingum	L. Kanawha	Kanawha	Kentucky	Cumberland	Average of Rivers	Railway
Cattle	$.15	$.15	$.20	$.0615	$.049	$.1165	$.057
Hogs	.15	.12	.25	.0615	.038	.1239	.066
Sheep	.15	.12	.16	.0165	.055	.1093	.071
Fzrm produce	.06	.12	.072	.034	.053	.069	....
Grain	.11	.12	.09	.0265	.034	.0961	.048
Furniture	.16	.17	.145	.03	.125	.126	.086
Sawed lumber	.10	.06	.10	.0153	.033	.061	.046
Coal	.09	.12	......	.004	......	.071	.016
Sand—gravel	.04	.06	.055	.0034	......	.0396	.0166
Averages	.112	.112	.134	.0328	.057	.0902	.0518

INDIANA'S ABILITY TO SUPPORT LIBERALLY HIGHER EDUCATION: ANALYZED AND COMPARED WITH THAT OF MICHIGAN, WISCONSIN, MINNESOTA, IOWA, ILLINOIS, AND OHIO.

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Indiana is at the center of the highly productive, populous eastern half of the nation. This half contains about nine-tenths of the nation's population, does over nine-tenths of the manufacturing and produces more than four-fifths of the mineral wealth. Indiana extends from Lake Michigan to the Ohio River and is crossed by all the chief east-west railroads. It lies in a region favored by having a good climate, much smooth land and fertile soil. It has no unproductive areas adjacent, except at the northwest corner (Lake Michigan). It is distinctly more fortunately located than are Wisconsin, Minnesota, and Iowa, which are decidedly more remote from markets and the center of population (which is in Indiana) and are crossed by far fewer great railroads, and have, except Iowa, large unproductive areas adjacent (the Great Lakes or the northern wildernesses). Michigan's location, except the southern part, is also less favorable than that of Indiana for the same reasons. Illinois may be slightly better located than Indiana in that it has more north-south railroads crossing it and includes more of the interior coal field, but it is farther from the great eastern markets. Ohio is nearer those markets than Indiana but is farther from the region of surplus food supplies and imports much food, by rail.

Area. Indiana is the smallest of the north central states. Ohio is one-ninth larger; Illinois, Michigan, Iowa and Wisconsin are each about 50 per cent larger; and Minnesota and Missouri are twice as large. Small area, however, is no proof of poverty. Superiority in resources, location, climate or population can more than offset the handicaps of small area. Superiority in a combination of these conditions is sure to do so. Numerous examples might be given. Contrast, for example, England and arid North Africa, over 100 times as large. The well endowed north central states show much less contrast, but fortunate Indiana has two and a half times the wealth and three times the population per average square mile which Minnesota has. In spite of Indiana's smaller size, she contains about 50 per cent more improved land than Michigan or Wisconsin and almost exactly as much as Minnesota or Ohio, and she has more people than Wisconsin, Minnesota or Iowa.

Furthermore, in many items of wealth such as quality and number of population, amount of manufacturing and many other sorts of work, area is of minor importance. In other items such as excellence of transportation and communication, small area is an asset. The state's

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extremes are less remote from the capital, from the institutions of learning, and from other points in the state to which the people wish to go.

The people of a small compact state can be more readily served by a few centrally published newspapers or other moulders of opinion than can those in a larger state. Hence smaller states present greater solidarity, and, as Ratzel and Semple have pointed out, greater progressiveness, if wisely led. Small area also means that fewer miles of improved roads are required.

The one great activity which is most clearly related to area is general agriculture. Leadership in agricultural production requires large area, and a small state is bound to trail behind larger states in total output unless superior in climate, soil or methods. This condition often leads to erroneous ideas as to the true agricultural wealth of small states. Indiana's agricultural wealth will be considered later.

Soil. The soil of Indiana is chiefly of glacial origin, as is that of most of the area of the north central states. However, a much smaller part of the state is excessively sandy than is true in Michigan or Wisconsin, or excessively rocky than is true in Wisconsin or Minnesota. A smaller share of the soil of the state is too damp (marshy) in Indiana than in Ohio, Michigan, Wisconsin or Minnesota. In average fertility the soil of Indiana is inferior to that of Iowa and much of Illinois, but is richer than that of the cooler and the wetter states, Ohio, Michigan, and Wisconsin. In very sandy sections of Michigan and Wisconsin and stony areas of Minnesota the soil is so infertile now, after having been burnt over, that little will grow on it except weeds, brambles, and small hardy trees of little value. In contrast nearly all of Indiana's soil is deep and of lasting fertility. Thus, in soil, Indiana is one of the most fortunate of the states.

Relief. In relief or ruggedness, Indiana also compares well with other north central states. It has less rugged land, proportionately, than Ohio, Illinois, Wisconsin, or Minnesota, and only a little more than Iowa or Michigan. (Much of Michigan's smooth land, however, is very sandy.) The smoothness of most of Indiana is highly favorable to the construction and maintenance of roads, railroads and streets. It thus favors communication, transportation, and manufacturing as well as agriculture.

Forests. In forest wealth, Indiana compares favorably with most north central states. Conditions for forest growth are exceptionally favorable, as is proved by the original superiority of her hardwood forests. The original forest is practically gone, but the cut of lumber in the last year available (1923) was 189,000,000 board feet, seven times that in Illinois and 20 times that in Iowa. It was also larger than that of Ohio. Although Michigan cut more lumber, much of it was unsuited to her needs, so that her excess of import over export was greater than in Indiana; this was also true of Illinois, Ohio and Iowa. Furthermore, most of these states are more remote from the southern source of lumber.

Minerals. Indiana is vastly ahead of the other north central states, except Ohio and Illinois, in coal, oil and gas. Wisconsin and Minnesota have none of these, Michigan has only a little coal and Iowa no oil. Indiana has an enormous tonnage of coal, more favorably situated in respect to the state's center of population and chief city than is the case in Illinois, Ohio and Iowa. This reduces the cost of haulage or of electrical transmission of the power developed by super-power plants near the mines. In non-metals, aside from fuels, Indiana is exceeded in production by Ohio and slightly by Illinois. Indiana surpasses the other north central states in both resources and production. In metals, Indiana resembles Ohio, Illinois, Iowa, Wisconsin, and many other states in producing none, or practically none. Indiana leads the world in the production of cut limestone.

Climate. Indiana's climate differs in certain important respects from that prevailing in certain other north central states. Indiana is in the corn belt whereas Michigan, Wisconsin and most of Minnesota are too cool for the extensive production of corn, one of the best crops. These more northern states receive enough snowfall often to interfere rather seriously with communication and transportation and often experience enough cold to be distinctly benumbing to man. They also receive less sunlight in winter because of their shorter days and greater cloudiness. In all of these respects Indiana is more fortunate than these three more northern states. There is little climatic contrast between Indiana, Ohio and Illinois, but the rainfall of Illinois is somewhat more uncertain than in Indiana, and this is notably the case in Iowa.

Agricultural Wealth. It is widely recognized that Indiana is a good agricultural state, but because of her small size, and consequent inability to lead in total production, her true standing is not fully realized. In proportion to area, Indiana is surpassed by not more than two or three states, and by only especially choice bits of the rest of the world. In total value of all crops, when comparative size is considered, Indiana is surpassed only by Iowa and Illinois, and by them only slightly. In the gross value of all farm products, which includes farm animals, Indiana is surpassed only by Iowa, in proportion to area.

In the production of leading crops, Indiana ranks very high. In average corn production (four recent years) per square mile, Indiana is surpassed in all America only by Iowa and Illinois, and only slightly by them; in wheat production, only by Kansas, North Dakota and Illinois (slightly); in hay production, by Ohio, Iowa (5 per cent), Wisconsin (5 per cent) and by some eastern states; and in oats production, by Iowa, Illinois and slightly by Minnesota and Wisconsin. These four crops, and cotton, are the chief American crops. In their production, Indiana has a high average position. Iowa, which specializes in corn, oats and hay, excels in these but produces almost no wheat; Illinois excels slightly in corn, oats and wheat; and Wisconsin excels in hay and oats but produces little corn or wheat. No other state surpasses Indiana in two of these four chief northern crops, when comparative area is considered.

The agricultural wealth of an area depends not alone on average yields but also upon the certainty of yield and the average price received at the farm. Certainty of yield depends chiefly upon climatic dependability, and the price chiefly upon market conditions. Indiana has a larger local market for her farm products than other north central state, except Ohio, and hence prices for farm products average higher at the farm in Indiana than in the other states, except Ohio.

In reliability of yield, Indiana is also notably fortunate. The rainfall from year to year is comparatively dependable and destructive frosts, hail and floods are relatively rare, although by no means lacking. Hence crop yields vary less from year to year than is the case in most states or parts of the world. The U. S. Department of Agriculture has recently investigated this significant matter and reports that, in the 15 years 1910 to 1924, the fluctuation in composite yields was but 25 per cent in Indiana. That is to say, the yield in the best year averaged 25 per cent greater than in the poorest year. In contrast with Indiana's 25 per cent, the range was 38 per cent in Illinois, 44 per cent in Minnesota, 46 per cent in Iowa, and 53 per cent in Missouri. The only north central state having as small a range as Indiana was Ohio (23 per cent). The comparative dependability of farming in Indiana is a very great asset indeed. Farming is a big enough gamble in Indiana. Yet in Iowa there is almost twice the uncertainty. The superiority of Indiana in this regard goes far to counter-balance the somewhat higher average yields of Iowa, a result of somewhat richer soil.

Population. Indiana, with a population of 3,000,000 in 1920, ranked eleventh among the states in total population and tenth in population per square mile. At that time other nearby states had the populations indicated (millions): Ohio 5.8, Illinois 6.5, Michigan 3.7, Wisconsin 2.6, Minnesota 2.4, Iowa 2.4. Thus Indiana had more population than three of the eight and almost the average for the group.

Hoosiers generally seem to feel rather discouraged about their state, fearing that the state must relinquish its position on the front rank of the states. What can be the basis for this pessimism? It may be that many people, seeing Indiana surpassed in total population, total wealth and size of her universities by near-by, larger, more populous states, have concluded that these conditions prove poverty and inferiority. They do not realize, perhaps, that Indiana is as favored by nature as almost any of the states, that the fact that Indiana is smaller than its neighbors only masks its wealth, and furthermore that large size and population have their serious drawbacks. Another reason why many Hoosiers have the impression that Indiana is falling behind is the large exodus from the state, and the cruel insinuation in the oft-repeated phrase "Indiana is a good state to have come *from*." The exodus from Indiana, however, is perhaps more an indication of strength than of weakness. The large rural population has contributed thousands to the rapidly growing cities. All over the world young people are leaving the farms for the cities. But the fact that Indiana has a relatively large rural population, and few great cities, is no proof of inherent inferiority. City life is attractive, but costly. No American cities are self-perpetuating so far as native American population is concerned. The cities receive people but give forth too few. The strength of any land is not in its tenements or apartments but in its owned homes. Indiana had a smaller percentage of its population living in rented homes than Ohio, Illinois or Missouri, and a larger percentage of unencumbered homes than any other of the five east-north central states.

Since neither the quality of the land nor the exodus of Hoosiers is an adequate basis for pessimism about Indiana, perhaps inferiority of the people themselves is the basis. But there are many bits of evidence indicating high quality rather than inferiority. Indiana has the smallest percentage of foreign born and children of foreign born of any of the north central states. It has a smaller percentage of negroes than Ohio or Illinois. It had in 1920 a smaller percentage of illiteracy than Illinois, Michigan, Ohio or Wisconsin. A recent report of the U. S. Bureau of Education reveals that Indiana had a larger percentage of its children graduating from high schools and attending institutions of higher learning than any other state east of the Mississippi River. Indiana has produced a notable number of leaders. Every Hoosier knows that Hoosiers have contributed much to literature. Riley, Lew Wallace, Eggleston, Joaquin Miller, Moody, Ade, McCutcheon, Tarkington, Nicholson, Gene Stratton Porter and others are honored the world over. Less widely known, but no less respected by competent judges are many Hoosier leaders in science, including Calkins, Slipher, Merritt, Kraus, Eigenmann, Coulter, Berkey, Wiley, Bryan and many others. About 50 of the leading 1,000 "starred" men of science were born in Indiana, which is a good proportion. Painters with international reputations who were born in Indiana include Chase, DeHaven, Garber and Steele. Eads is honored by all engineers, and Wilbur Wright shares with his Ohio born brother credit for the airplane. Also numerous notable executives, city superintendents, and presidents of railroads, banks, big businesses and colleges were born in Indiana.

Indiana has likewise taken a leading role in the consolidation of schools, in the improvement of roads, in the winning of a fairer place for labor (consider Zueblin, Debs, Green). All these are evidences of good quality and not inferiority of stock. Hence there appears to be no real reason for exceptional pessimism.

Occupations. The people of every diversified region earn their living and their tax money in a variety of ways. In so far as a state's ability to support higher education is concerned, it makes a good deal of difference as to the proportions of the workers engaged in different types of activities. If one activity occupies a large share of the workers, the state's prosperity will suffer when the demand for that product decreases, or conditions are unfavorable for that product, be it automobiles or corn.

All of the north central states are relatively fortunate in the diversity of activities and in the widespread markets for their products. They are not likely to suffer sharp slumps. But in this fortunate group of states, Indiana is perhaps at the top. It is a great agricultural state, but only 30 per cent of the people are on farms. A larger percentage, such as is present on farms in Iowa, Minnesota, Wisconsin and Missouri is probably undesirable, because of the lesser efficiency and prosperity of farmers. About 32 per cent of Indiana workers are engaged in manufacturing. This may be contrasted with 20 per cent for Iowa, 22 per cent for Minnesota, 25 per cent for Missouri, 33 per cent for Wisconsin, and 42 per cent each for Michigan and Ohio. It is likely that the latter percentages (42 per cent) are less desirable than Indiana's ratio. About one-fifth of Indiana's workers are engaged in transportation and communication, a larger percentage than in the other near-by states, because Indiana has most miles of track, most miles of wires and most traffic in proportion to area and population. About one-fifth of the workers in Indiana are engaged in trade, probably about the same percentage as in the other states. In mining and quarrying, Indiana's 3.2 per cent is greater than that of Michigan, Wisconsin, Iowa or Minnesota with their lesser mineral resources, or than Ohio with its large industrial population. The percentage in Illinois is practically the same as in Indiana, as is also true of manufacturing.

Manufacturing. In value added by manufacturing (in 1919) Indiana's total was over three times that of Iowa, over twice that of Minnesota, one-half more than that of Missouri, and greater than that of Wisconsin. It was 40 per cent of that of Illinois, and 35 per cent of that of Ohio.

In manufacturing, Indiana is likewise characterized by diversification. No industry or small group of related industries dominates the state. Hence the prosperity of manufacturing is more stable and assured than in Michigan, for example, with its dependence upon the automobile industry, or in Ohio with steel and rubber making up such a large share. The chief industries of Indiana with the percentage of all persons engaged in industry were as follows: railroad shops and the construction of railroad cars, 10.7; iron, steel and products, 9.6; automobiles, bodies and parts, 9.3; foundry and machine shop, 6.8; furniture, 4.8; electrical apparatus, 4.2. This leaves more than half of all industrial workers for the hundreds of lesser industries. The fundamental character and diversity of these chief industries is indicative of sustained ability to pay taxes.

Wealth. From time to time the Federal Government has compiled estimates of the wealth of the states. The last estimates were for the last day of 1922. They showed that Indiana, with $2,942.00 per capita, had a slightly smaller per capita wealth than Ohio ($3,045), Illinois ($3,295), Minnesota ($3,443), or Iowa ($4,274), but that it surpasses slightly Michigan ($2,883) and Wisconsin ($2,887). In the percentage of increase in per capita wealth between 1912 and 1922, Indiana with 52 per cent far exceeded Illinois (25), Iowa (24), and Minnesota (37). Ohio showed the largest gain (65.7 per cent). In wealth per square mile, Indiana far exceeded all of these states except Illinois and Ohio. The figures are, in thousands of dollars per square mile, Indiana 245, Minnesota 105, Wisconsin 143, Iowa 188, Michigan 199, Illinois 347, Ohio 465.

It is thus seen that in reported wealth Indiana compares very favorably with most near-by states. Moreover, special conditions have led to an exceptional increase in the proportion of unreported wealth.

The wealth of Indiana as revealed by the tax assessors has been decreased by the undue failure to report property at its full valuation or to report intangibles. One cause of this is the general property tax imposed by the constitution of 1852. Most of the taxes of Indiana have been raised by the general property tax with no graduation of tax rates, whereas in other north central states large shares are obtained from income, corporation, inheritance and other taxes. For example, in 1922, Ohio, Illinois and Iowa raised only about one-third of their income from property taxes, and Minnesota only about one-fourth. Further, in those states, property is classified, and the more intangible types are taxed at a low rate, so that there will not be much inducement not to report them. Recently, to be sure, Indiana has raised a significant fraction by a gasoline tax, but this is too recent to affect the 1922 estimates of wealth. The fact that nearly all the taxes have been raised by the general property tax without classification of property thus has made the rate high. Another influence decreasing reported value is the prohibition by the constitution of a state debt. While other states have reduced, for the present, their tax levies by borrowing extensively, Indiana has been compelled to raise more money now. A third way in which the reported wealth has been decreased is by the mortgage exemption. Because the property tax rate is so high, many small property holders have taken out mortgages, to reduce their taxes, and have invested the money in tax exempt or unreported securities.

The fact that Indiana has relatively few large cities with their large industries and ready tax money has likewise increased the tax rate, and hence the tendency to reduce valuations and not to report intangibles. Intangibles are entirely omitted from the 1922 federal estimate of wealth.

For these reasons it is certain that Indiana's wealth is considerably greater than shown by the tax assessors. If the difference is only 30 per cent instead of the 20 per cent assumed by the makers of the 1922 estimate, Indiana's per capita rate is higher than Ohio or Illinois, as well as that of Michigan, Wisconsin and Missouri. Another indication that Indiana is not poorer relatively than Ohio and Illinois is that as much money is spent, per capita, for automobiles, telephones and apparently for luxuries and outside investments. Yet, at the last available report, the amount of actual money in Indiana was reported as only one-fourth that in Illinois, instead of one-half, as should be expected. This certainly is suggestive of a failure to report in Indiana!

In reported total wealth, Indiana exceeds Minnesota and Wisconsin. If the unreported wealth in Indiana is proportionately as great as various conditions suggest, Indiana may also surpass Iowa and Michigan. The greater wealth in Ohio and Illinois is not great enough to more than offset their greater population, as already noted.

The total reported wealth of the other states should be reduced by the amounts of their state debt, which in 1923 were as follows: (millions) Iowa 15; Minnesota 20; Illinois 26; Ohio 30; Michigan 69. Also, as mortgages are not deducted in statements of total wealth, and most of the farm mortgages of Iowa are held by easterners, they should be deducted. Nearly one-half of Iowa's wealth is her farm property. Two-thirds of the farms are mortgaged, and the mortgages subtracted nearly 30 per cent of their value. Thus, it appears that the real wealth of Iowa's people is notably less than reported, and probably distinctly less than the true total wealth of Indiana. Of the north central states, Indiana and Ohio have the smallest percentage of mortgaged farms, and in Indiana mortgages make up the smallest ratio to the value.

Summary and Conclusions. Indiana clearly is one of the most fortunate of the states in regard to location, climate, relief, soil and natural resources. It is distinctly above the average of the north central states. In wealth per average square mile it far exceeds all of the other north central states except Illinois and Ohio; in wealth per capita it clearly exceeds Michigan, Wisconsin and Missouri, and probably also Illinois and Ohio, which states have a smaller percentage of unreported wealth (Indiana's general property tax and constitutional bar against state debt lead to a high general property tax rate, and hence to exceptional failure to report all wealth). In percentage of increase in per capita wealth 1912 to 1922, Indiana exceeds Illinois, Iowa and Minnesota and is only slightly behind Michigan, Wisconsin and Ohio. In total reported wealth, Indiana exceeds Minnesota and Wisconsin, and in true total wealth probably also Iowa and Michigan. The population of Indiana is greater than that of Wisconsin, Iowa or Minnesota, and only slightly less than that of Michigan. It is almost the average for the states between which comparisons are being made. Indiana has an exceptionally large percentage of its population graduating from high school and hence especially interested in higher education. Yet in Indiana there are only two universities offering considerable graduate work, one of which (Purdue) has given no doctorates. In Ohio there are six advanced institutions, including three state supported universities; in Illinois there are, besides the well-supported state university, the University of Chicago and Northwestern University. Iowa and Michigan each have two state-supported institutions offering much graduate work.

The most direct result of this disparity in facilities for higher education in Indiana and in neighboring states is in the number of people leaving this state to seek higher education. In 1923, 4,353 graduates of Indiana high schools attended outside institutions taking out of the state on the average about $1,000 apiece, a total of about $4,350,000 or nearly twice as much as the appropriations that year to both Indiana and Purdue Universities. On the other hand, only about 2,175 students came into Indiana from outside of the state. It thus appears that Indiana would be ahead financially if, by expending $2,000,000 a year additional on her universities, she attracted as many outsiders to Indiana as went outside for higher training. Other north central states have succeeded in attracting more students than they send out. The loss to Indiana by the present situation is real. Not only is over $4,350,000 of money spent elsewhere, but many of the students who graduate from outside institutions do not return to Indiana, and hence Indiana loses their services, and the investment she had made on their elementary and high school education. Unless Indiana's universities are notably improved, the loss will continue, and increase. Already Michigan, Ohio, Wisconsin, Minnesota and Iowa each have two or three times as many graduate students as Indiana, and Illinios 14 times as many. The same general situation obtains in respect to professional students.

It appears, therefore, in conclusion, that in respect to location, climate, topography, soil, resources, quality of people, dependability of income, per capita and total wealth and in certain other respects, that Indiana is at least as able to support higher education as is Wisconsin, Minnesota, Iowa, or Michigan. This means an appropriation for Indiana's two universities of at least the average made by these four states, namely, $5,440,000 annually, which is $244,000 more than twice the present Indiana appropriation ($2,598,173). The appropriation for the normal schools must likewise be doubled in order to reach the level of the other states of this group. Furthermore the damage done by the large deficiencies in appropriations during the past decade should be corrected, so far as possible, by a large emergency appropriation for badly needed repairs, books, equipment and building.

Finally, Indiana is very rich in numerous ways, at least as rich as the average seven north central states under consideration and hence is able liberally to support higher education. The present appropriation must be more than doubled merely to equal the average made by the four poorer states of the seven. And Indiana can afford to be a leader. If the state's great resources and other advantages are to be wisely used, there is need for many well trained men and women.

BELL CREEK—FALL CREEK VALLEY.

ANNICE CARTER AND LOUISE PAINTER, MUNCIE.

The Bell Creek—Fall Creek Valley is a continuous trough extending from Buck Creek southwestward. Bell Creek occupies the northern part of this valley and Fall Creek the southern part. The continuity of this valley suggests the possibility of formation by a single stream. Phinney[1] recognized this and in speaking of the valley of Fall Creek, in the vicinity of Middletown, he says: "This channel continues northward into Delaware County, where it is known as the 'Glade', a long swampy tract, which extends to within four miles of Muncie." The trend of the small valleys which are tributary to this valley suggests the existence, at one time, of a single northward flowing stream. On the other hand the width of the valley goes to prove that this single stream was a southward flowing stream. The valley of Bell Creek, near its mouth, is approximately 300 feet wide. Farther south, in the Glade (marked B in figure 1), the valley is from 1,800 to 2,000 feet wide and continues on south for several miles at about this width.

The tributaries to Bell and Fall creeks, suggesting the existence of a single northward flowing stream, have their origin on the inner slope of the Mount Summit Moraine. These are consequent streams, thus giving them a northwest trend. In this area the inner slope of the moraine is very close to the Bell Creek and Fall Creek drainage systems, which made the tributaries join the master stream at an unusual angle. Another evidence of the morainic origin of these tributaries is the fact that no tributaries are found on the northwest side of the stream. Farther south than is shown on the map, the tributaries are normal. They have their source on the inner slope of the moraine but Fall Creek, in this part of its course, is separated from the morainic ridge by several miles of ground moraine. This has given the tributaries a chance to join the master stream in the natural, dendritic pattern.

The south-flowing stream which carved out the Bell Creek—Fall Creek Valley, carried glacial waters and post-glacial drainage from Delaware County and vicinity until White River came into existence. With the establishment of White River and Buck Creek a short tributary flowing northward into Buck Creek, was established in this trough, and by headward erosion moved southward until it reached the Glade, near the southern edge of Delaware County. The first capture of this north-flowing stream was No Name Creek, the next was Little Bell Creek, and then the tributary that is now the upper portion of Bell Creek. At present the divide is in the Glade, a short distance south of the county line. If diversion of drainage northward is continued, Bell Creek will work across the Glade and capture the upper waters of

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[1] Phinney, Geology of Henry County: Ind. Dept. Geol. and Nat. Hist., 15th Ann. Report, 1885-86.

"Proc. Ind. Acad. Sci., vol. 36, 1926 (1927)."

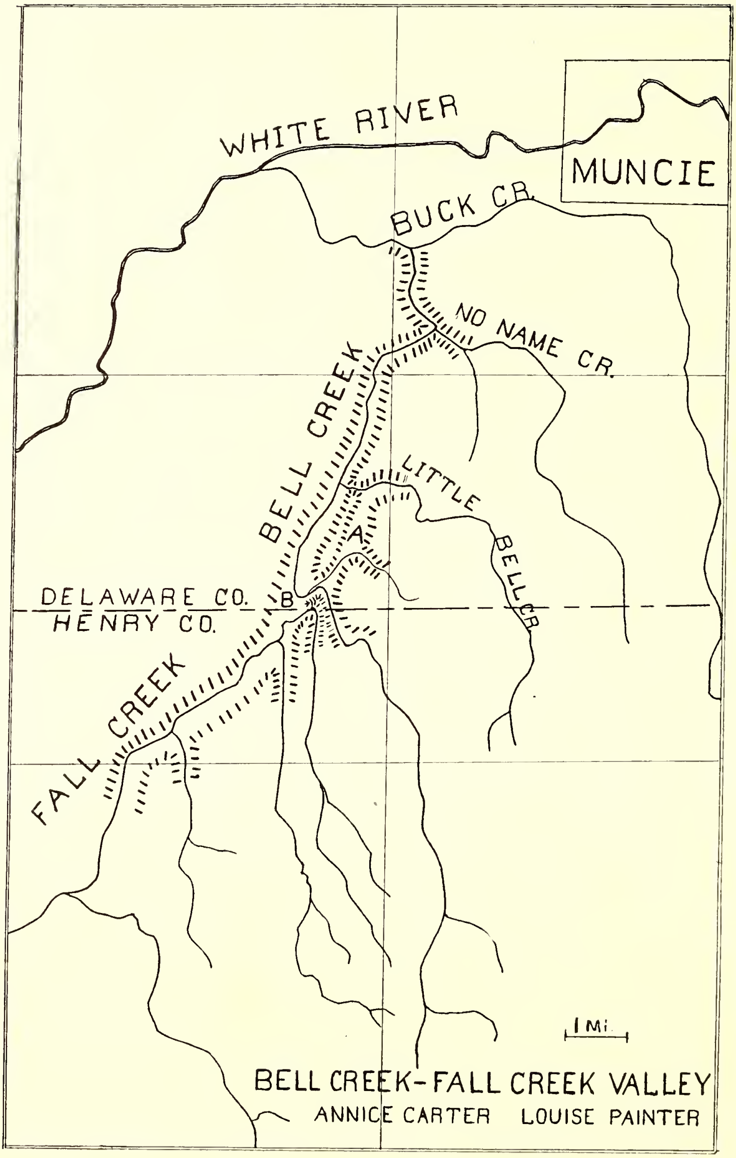

Fig. 1. Drainage Changes in the Bell Creek—Fall Creek Valley.

Fall Creek, but the channels of both Bell and Fall creeks have been dredged, and the depth to which each is dredged may prevent further natural changes in drainage.

Fred J. Breeze[2] has mapped and described four distinct valleys through which glacial water flowed southward across the Mount Summit Moraine. In each has occurred a reversal of drainage, and the northern part of each glacial spillway is drained by a north-flowing tributary of White River. These four cases of drainage changes are similar to that which has occurred in the Bell Creek—Fall Creek Valley.

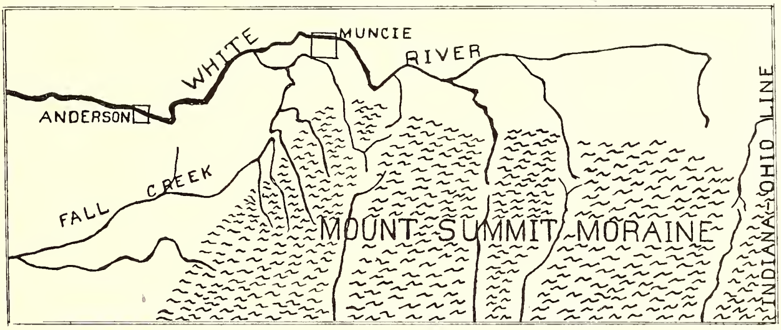

Fig. 2. May Showing the Relation of the Bell Creek—Fall Creek Valley to the Mount Summit Moraine.

When the master stream flowing southwest was in existence, Little Bell Creek flowed through the now abandoned valley, marked A in figure 1. This stream now joins Bell Creek about one and one-half miles farther north. Its new valley is so narrow that some have thought it to have been cut out by man. However, the natural channel can be seen along the present dredged channel.

All of these changes have taken place since the Wisconsin glacial stage. The valleys are all in Wisconsin drift and do not reach bedrock anywhere in this locality.

The Bell Creek drainage is well shown on the colored soil map of Delaware County in Soil Survey of Delaware County, 1915, U. S. Bureau of Soils.

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[2] Breeze, Abandoned Channels in Randolph and Delaware Counties, Indiana, Proc. Ind. Acad. Sci., 1922, pp. 95-98.

PORTER'S CAVE AND RECENT DRAINAGE ADJUSTMENTS IN ITS VICINITY.

ARCH R. ADDINGTON, INDIANA UNIVERSITY.

Porter's Cave is mentioned in the Indiana State Geologist's Reports as early as 1875.[1] In the report for that year there is a brief description of Miller's Cave, as Porter's Cave was then known. Traditional accounts indicate the cave was known to the Indians and early settlers of the county. Indian flints have been found within the cave but these have long since been removed and their disposition is unknown. The following is taken from the 1875 report.

"Miller's Cave, a mile and a half northeast from the latter, (meaning Roger's Cave) on section 33, township 12, range 2, is surrounded by wild canyon-like scenery, romantic and interesting. The spring here has a fall of 40 feet, and by a turbine drives a boulder "corncracker" mill.

"The cavern is 40 feet wide and 4½ to 5 feet high for 100 yards, where there is a long room 7 feet wide and 15 feet high; beyond the water is deep and the roof descends to within a foot or two of the water. It has been traced as Mr. Charles Dow states, more than a half a mile to its source in two sinks, one in Morgan County, the other in Owen County. In wet weather the cavern is sometimes filled to its utmost capacity and the water in the pool is then 25 feet deep."

The statement referring to the source in two sinks, one in Owen, the other in Morgan County, is significant. No mention is made of the dry valley entering the gorge near the cave entrance. The dimensions given are very likely based upon estimates rather than upon careful measurements.

Another description of the cave is given in the State Report for 1883.[2] This contains a somewhat more detailed account of the cavern interior. Mention is made of an opening to the cave on the opposite side of an elevated ridge, three-quarters of a mile from the cave outlet. No reference is made to the dry valley near the cave.

The next account of Porter's Cave is that given by Blatchley in the 21st report.[3] His description of the cave is an accurate and most pleasant one to read. He mentions, "the source of the stream which flows therefrom is about one-half mile northeast in Morgan County."

That a case of valley abandonment has recently occurred in connection with Porter's Cave seems to have escaped the notice of these early writers. This is no discredit to their efforts for they were primarily interested in the caves and in animal life found therein. In this respect Blatchley's report upon "Indiana Caves and Their Fauna" is the most valuable source of information concerning Indiana Caves.

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[1] Geological Survey of Indiana, 1875,—p. 321.

[2] Rept. Ind. Geol. and Nat. Hist. f. 1883, pp. 78-79.

[3] Rept. Ind. Dept. Geol. and Nat. Res. f. 1896, p. 124.

"Proc. Ind. Acad. Sci., vol. 36, 1926 (1927)."

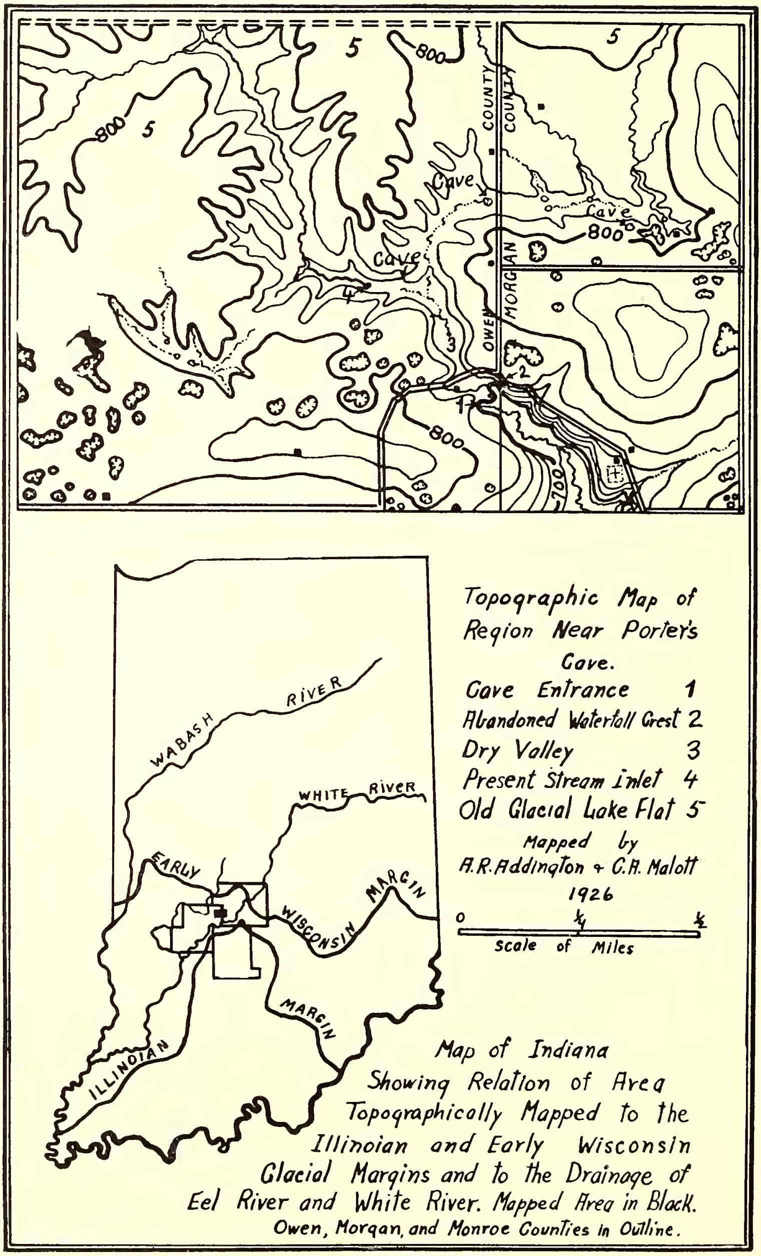
5
800
5
800
COUNTY
COUNTY
Cave
Cave
Cave
800
4
3
OWEN
MORGAN
2
1
800
700
Topographic Map of Region Near Porter's Cave.
Cave Entrance 1
Abandoned Waterfall Crest 2
Dry Valley 3
Present Stream Inlet 4
Old Glacial Lake Flat 5
Mapped by A.R. Addington & C.A. Malott 1926
0 ¼ ½
Scale of Miles
WABASH RIVER
WHITE RIVER
EARLY WISCONSIN MARGIN
MARGIN
ILLINOIAN
Map of Indiana Showing Relation of Area Topographically Mapped to the Illinoian and Early Wisconsin Glacial Margins and to the Drainage of Eel River and White River. Mapped Area in Black.
Owen, Morgan, and Monroe Counties in Outline.

Fig. 1. The area in the topographic sketch is a slightly modified plain, characteristic of a transition zone, between the glacial lake flat of Lake Quincy located to the north of the area and the more dissected portion of the plain to the south.

It was my privilege to visit Porter's Cave for the first time the summer of 1926. During the course of this visit and of succeeding ones, it occurred to me, that a brief account of the cave and of drainage changes intimately associated with it might prove of interest. Such is the occasion of this paper.

Location of Area and Cave. The region involved in this discussion is an area including little more than one and one-half square miles in northeastern Owen County and western Morgan County, Indiana (fig. 1).

The exact location of the area is section 33 and the west one-half of section 34, township 12 north, range 2 west. Within the area is the cave known as Porter's Cave, the entrance of which is located near the bend in the road in the southeast ¼ of section 33 (fig. 1). The cave may be reached by a good stone road from Gosport from which it is distant six miles in a northeasterly direction.

Drainage and Topography. The country near Porter's Cave drains to the west fork of White River and to Eel River. Drainage passing through the cave is tributary to White River. One and one-half miles northwest of the cave entrance there is a low divide separating Eel River and White River drainage. The stream flowing from the cave entrance is known as Butler Creek. This debouches into White River a short distance east of Gosport.

Subterranean drainage, characteristic of an area underlain with limestone rock, is much in evidence. Several springs, most of them small, appear in the ravines near the contact of the limestone with the more impervious strata beneath. The springs represent the reappearance of water that has previously soaked into the soil and rock strata of the plain.

Topographically, the region is a plain characterized by a youthful stage of valley development. The conditions of rock structure are such as to favor the formation of sharp ravines, bordered by cliff-like margins. The ravines oftentimes have water falls in their headward portions. One such is shown in the accompanying topographic sketch (fig. 1).

In many places the plain is dotted with sink holes, most of them small but varying considerably as to depth. It is possible that some of the larger sinks owe their present form to the excavation of glacial materials from their basins, the origin of the basins antedating the materials derived from the early Wisconsin drift margin.

North of the area mapped, the country is a plain practically unmodified by drainage. It is referred to by the people of the vicinity as the "Flats." The elevation of this plain is slightly more than 800 feet. Remnants of it are represented in figure 1 (5). The "Flats" constitutes a plain of considerable extent and represents a part of the lacustrine basin of Glacial Lake Quincy, and is representative of a transition zone situated between the lake flat and the more dissected portions of the plain which have been developed by tributaries adjusting their valleys to the valley level of White River.

In the southern part of section 33 and 34 there is a gorge approximately 80 feet in depth. At the upper end of the gorge two valley heads are present in one of which the entrance of the cave is located, (see 1 of figure 1) while the other ends in a ledge of rock, over which a waterfall formerly descended to the gorge below. (See 2 of figure 1).

Above the ledge a dry valley (see 3 of figure 1) extends about one-fourth mile in a northerly direction at which point it branches, one prong extending eastward into Morgan County, the other extending westward a short distance at which place a stream of water is found entering a cavern (see 4 of figure 1), the inlet for Porter's Cave. From this point on the valley contains a stream that has its origin upon the "Flats" located to the north and west. (See 5 of figure 1.)

Near the place where the dry valley forks and on the north side of the left valley prong, a small entrance to a low cave is found. Placing an ear at the small opening it is possible to hear water flowing rapidly along the subterranean channel. This is thought to join with that issuing from the entrance to Porter's Cave.

In the dry valley which extends eastward into Morgan County it is possible to enter subterranean passages at two points, within the valley. One of these is a small sink hole, near the road separating Owen and Morgan counties; while the other is in Morgan County, about mid-way between the points where streams are observed to disappear in sinks in the dry valley. The general direction of water flow in these places is westward. The elevation of the subterranean channels is 35 feet above the outlet at Porter's Cave.

It seems that the statement given in the 1875 report, where the writer says, "The source is in two sinks, one in Owen and the other in Morgan County," is correct. The topographic map is suggestive of this condition.

Geology. The bed rocks exposed at Porter's Cave are of Mississippian Age. The formations present are the Riverside sandy shale member and the Harrodsburg limestone.

The Riverside member is a muddy sandstone, impervious to water but disintegrates rapidly under the influence of weathering. It grades rather gradually into the lower part of the Harrodsburg above, so that the actual point of contact can scarcely be determined with precise accuracy.

The Harrodsburg is a rather fine layered, coarsely crystalline, fossilliferous limestone. In the lower part of the limestone the character changes to that of a limy shale, oftentimes with geodes distributed throughout the mass of shaly layers.

It is more resistant to weathering than the Riverside shale member and where it overlies this formation along valley sides it forms overhanging cliffs. This result of lithologic control is beautifully illustrated at the entrance of Porter's Cave and again at Roger's Cave one and one-half miles southwest of the former.

Porter's Cave and the subterranean drainage associated with it is developed in the Harrodsburg limestone. The stream issuing from

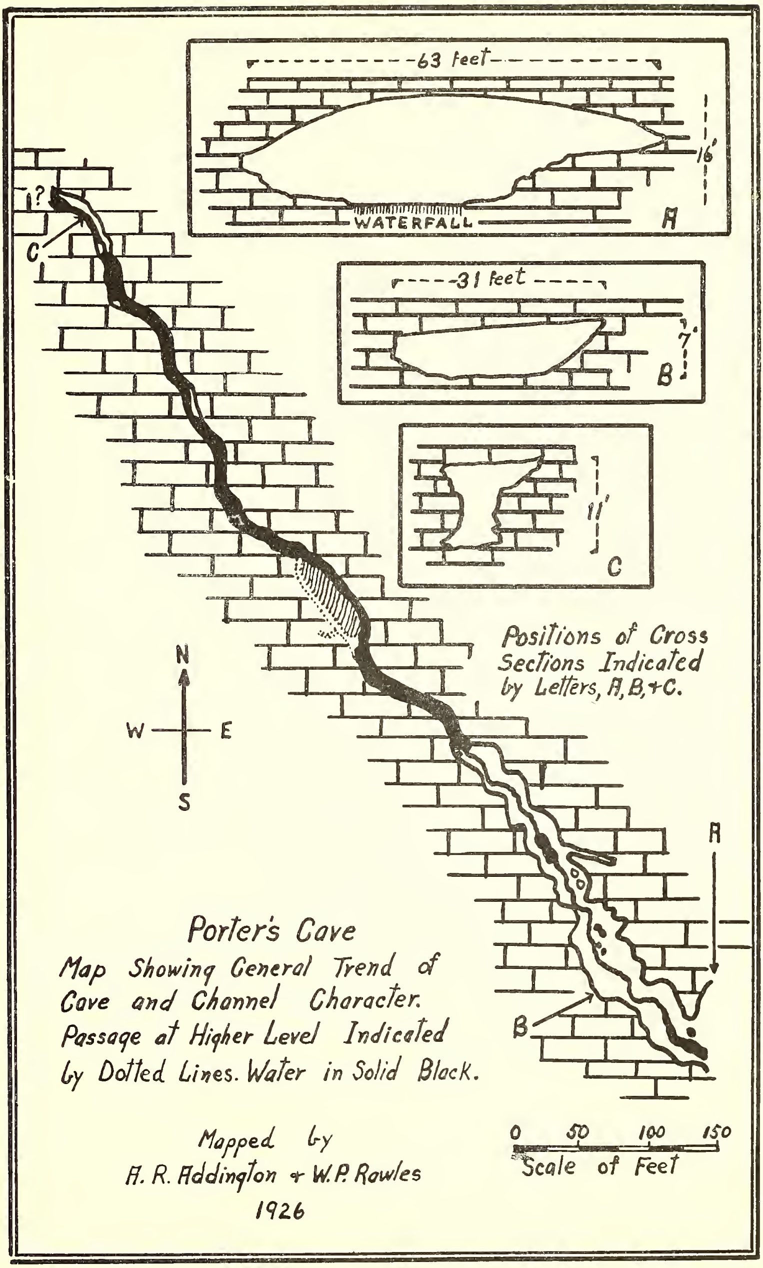
63 feet
16'
WATERFALL
A
31 feet
7'
B
11'
C
?
C
Positions of Cross Sections Indicated by Letters, A, B, + C.
N
W
E
S
A
B
Porter's Cave
Map Showing General Trend of Cave and Channel Character. Passage at Higher Level Indicated by Dotted Lines. Water in Solid Black.
Mapped by
A. R. Addington + W. P. Rowles
1926
0 50 100 150
Scale of Feet

Fig. 2. The cross sections indicate progressive channel widening due to the influences of weathering. The whole trend of the cave is essentially a joint controlled feature.

the cave mouth flows over a limy shale layer characteristic of those found near the lower part of the Harrodsburg formation.

The normal dip of the rock is to the west and south. The entrance of Porter's Cave is at an elevation of 735 feet. On a similar rock layer one and one-half miles southwest at the entrance of Roger's Cave, the elevation is 700 feet, which gives an average dip of 20 feet to the mile for the rock layers in this vicinity.

Porter's Cave. Porter's Cave (fig. 2) is a narrow water worn channel, that trends in a general northwest direction from the entrance. The cave insofar as it was mapped is somewhat winding but the bends are not sharp so that light from the entrance is visible at a point 350 feet within.

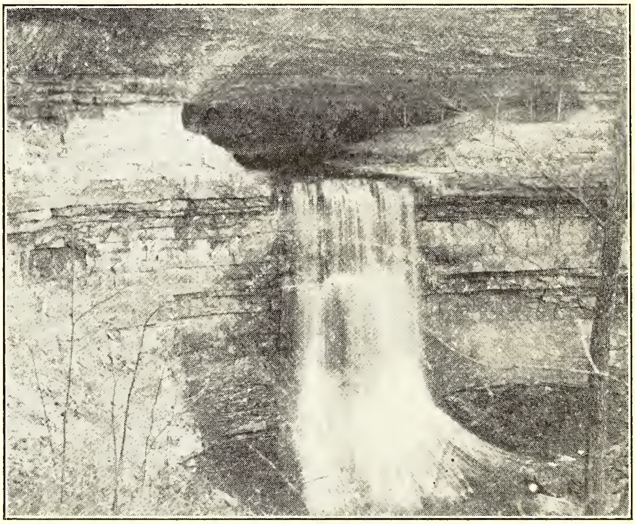

Fig. 3. The entrance to Porter''s Cave. The waterfall is 17 feet wide and drops a vertical distance of 35 feet. The crest of the waterfall is 15 feet lower than the ledge of rock marking the crest of the abandoned waterfall in the adjacent valley head.

The entrance (fig. 2A) is a great arch of limestone, 63 feet wide and 16 feet high at the place the above cross section was taken. The arch overhangs a waterfall 17 feet wide, the waters falling 35 feet to the bottom of the gorge (fig. 3). The entrance faces nearly due east. Early of a morning the sun lights the interior for a considerable distance. The majestic archway, the sparkling water and the gradual deepening of the interior shadows is a sight not soon forgotten by the observer.

From the entrance the passage rapidly narrows to 30 feet wide and 7 feet high. The roof is an immense slab of limestone that appears to be tilted but is more likely a result of the cross bedded character of the limestone layers. At 300 feet the channel narrows to 10 feet in width but is about 15 feet high.

Three hundred eighty-nine feet from the entrance the channel is nearly blocked by a magnificent deposit of flowstone. A ladder leads to the top of this where a narrow passage floored with slippery clay soon joins the main channel. To the right of the base of the ladder (fig. 4) a low narrow channel extends along the margin of the flowstone-deposit. Near the top of the ladder a small stream of water enters the main channel and trickles down over the flowstone. This seemingly insignificant stream has been the main factor in supplying the mineral matter for the huge flowstone deposit.

At 780 feet, there is partial collapse of the cavern roof. Huge blocks of rock are tilted at precarious angles. Considerable water trickles into the cave at this point. I estimate the source of this water to be from a small spring located on the side of the dry valley (see 3 of figure 1) the waters from which soon disappear in a sink hole in the bottom of the valley.

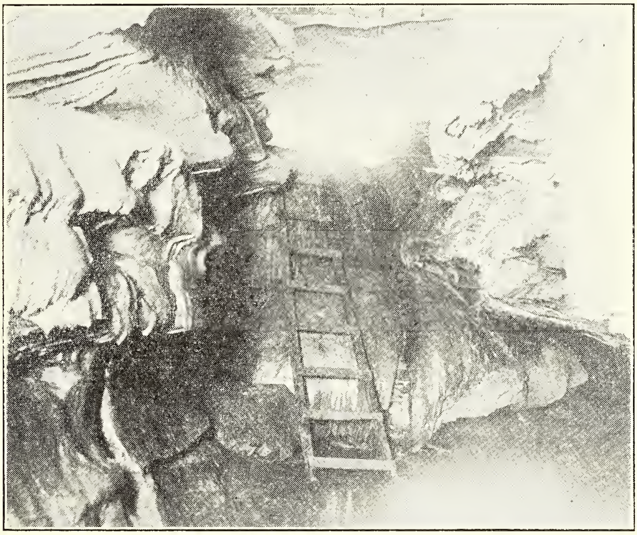

Fig. 4. The ladder leans against an immense deposit of flowstone. The light at the top is due to the intensity of the flash which was placed in the upper channel. At the base of the ladder a channel nearly filled with water extends along the right of the flowstone deposit.

At 800 feet the channel is only four feet in width at the base, and 11 feet high being somewhat wider at the top.

At a distance of 832 feet from the entrance the channel is 12 feet wide but only 18 inches high. Further progress necessitated crawling through water and mapping was abandoned at this point.

The great width of the entrance is due for the most part to the efficiency of weathering, particularly changes of temperature involving freezing and thawing. On the interior the temperature remains practically constant so that rock disintegration due to physical weathering processes is absent.

On the interior of the cave, near the entrance, are several pot holes. These are indicative of the swirling currents of water that at times pour from the entrance. Mr. Whitaker, manager of the cave, states that during the high waters of 1913, the stream flowing from the entrance was nearly four feet deep and the noise of the falling water was plainly audible at his home, three-fourths mile distant. The high water mark is about the middle of the notch shown at the left margin of the cave entrance (fig. 3).

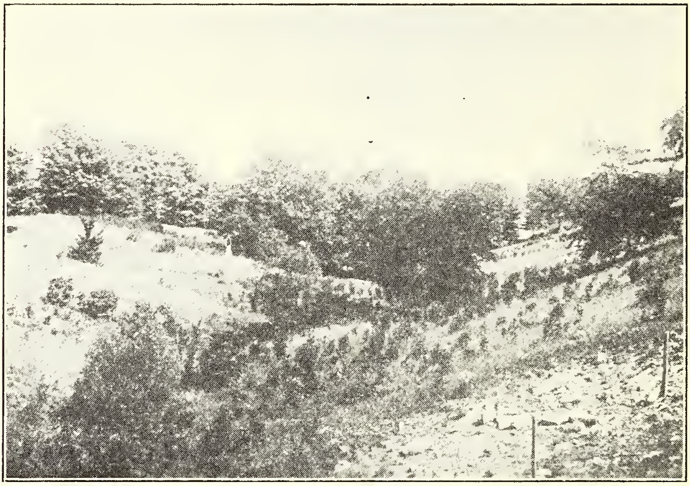

Fig. 5. A view of the valley recently abandoned. A short distance beyond the spring house, middle background, the valley bends to the left. Rock fragments in the foreground are from a quarry in the Harrodsburg limestone.

At 279 feet from the entrance, water covers the channel from side to side. Except for a short boat trip, it is necessary to wade in water of moderate depth while exploring the cave. At one or two places gravel deposits were found in the channel. The greater part of it, however, has a floor of solid rock.

The narrow channel-like character of the cave and the absence of any extensive rooms would seem to indicate that the cave is relatively young. The general direction of extent is an example of joint control over direction of subterranean waters.

The Dry Valley. Mention has already been made of the dry valley which enters the gorge near the cave. At this point there is a ledge of rock marking the crest of a former waterfall, at the base of which a considerable pot hole had been excavated. This is now somewhat filled in by by the slump of material from the sides of the gorge and by the occasional fall of material weathered from the surrounding cliffs.

Above the waterfall crest a dry valley may be followed about one-fourth mile to the place where it forks, one prong extending into Morgan County, the other containing the stream which reappears at the cave. That this valley was not occupied by a stream for a very long time is evidenced by the ravine-like character of the valley (fig. 5) and by the short distance which the waterfall has receded. No large stream flowed through the valley as indicated by its small size.

The abandonment of the valley by the stream has been at a very recent date. This conclusion is based upon the relatively slight modifications of the valley since the stream occupied it, the relative freshness of the waterfall crest and slight amount of recession of the crest, the youthful character of the drainage above the present inlet (fig. 6), and young stage of development of the cavern interior.

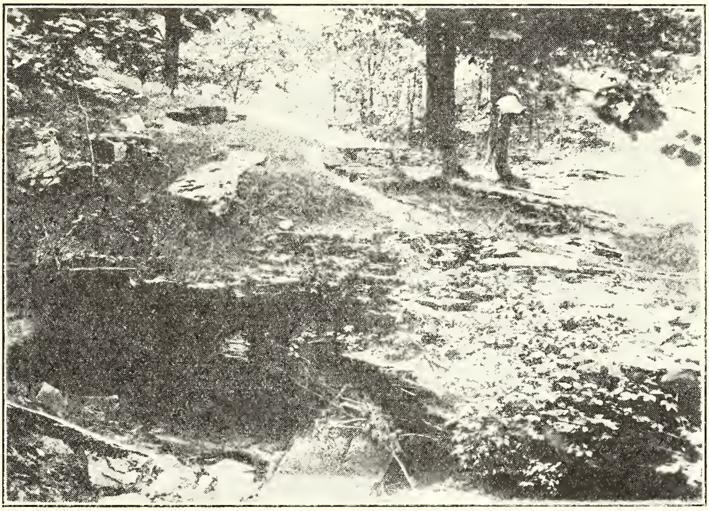

Fig. 6. The dark place in the left foreground is the inlet for water which appears at the entrance of Porter's Cave. Near the base of the tree in the middle foreground a portion of the abandoned valley can be made out.

Relation to Glaciation. The region was covered by the ice of the Illinoian glacial lobe (fig. 1). The well log at Quincy indicates a glacial advance, an interglacial stage, and a readvance of the ice in this area. The modifications of drainage which the Illinoian ice and drift produced in this vicinity are perhaps too far in the realm of speculation to merit a consideration. Rather than state it as a fact I offer the suggestion that the drainage development here is Post-Illinoian, a suggestion based upon the youthful character of the drainage.

The conditions of rock structure are very favorable to the rapid development of gorge-like valleys. Hand in hand with the deepening of these gorges across the plain a subterranean circulation would be established in the limestone uplands. If the gorges are Post-Illinoian then the cave and the adjacent sink hole topography are also Post-Illinoian.

The area is marginal to the Early Wisconsin Drift. Along the margins of this drift Glacial Lake Quincy had it inception. Similar to any marginal lake formed along the border of an ice mass, this lake had a number of overflow outlets. The positional relation of the lake flat to the Porter's Cave region is such as to suggest a partial escape for the lake waters in the vicinity of the cave.

If it is not too much speculating I venture the suggestion that during a short period overflow from the lake was by way of the valley now abandoned and at the same time part of the waters were escaping by subterranean passages along the route of the cave, the subterranean routes receiving more water than they could transmit.

The abandonment of the valley by the stream and the diversion of the waters to subterranean routes would come as a result of lessened supply due to the lake finding a lower outlet. If this assumption is correct, the drainage condition near the cave had its inception during the Early Wisconsin Glacial Stage.

Before the exact relation of Lake Quincy to the Porter's Cave region can be ascertained, a detailed study of the lake basin with a view of determining the various overflow outlets will be necessary. This in itself is no small matter. An overflow outlet associated with the drainage through Roger's Cave is present two miles west of the area discussed in this paper.

Perhaps this account is somewhat disappointing because of the uncertainty of conclusions expressed, but such must be the case until more definite knowledge is obtained. There can be no question as to the fact that the valley has been abandoned in favor of the cave channel. As to the time of abandonment and the causes leading up to it there is some room for doubt. So far as I am aware no account of drainage change near Porter's Cave has ever been written. It seems to me an interesting phenomenon of this small area.

NOTES ON THE AREAL GEOLOGY OF MIAMI COUNTY, INDIANA.

W. E. THARP, BUREAU OF SOILS, U. S. DEPARTMENT OF AGRICULTURE.

A soil survey of Miami County during the summer of 1926 afforded opportunity for some observations on the areal geology of that interesting region.

The southern three-fourths is, for the most part, a till plain of the "sag and swell" type, so common throughout north central Indiana. The local relief, except in the immediate vicinity of streams, does not usually exceed 15 or 20 feet. Occasional low mounds and flattish ridges stand out more prominently, but there are many square miles where the undulations are so gentle that the plain approaches flatness.

Throughout the northern quarter of the county the relief is more pronounced. In its larger aspects it is structural, the elevations and depressions being disposed in that irregular manner which marks the difference between the work of ice and that of water.

The observing traveler will also note that the landscape in this last named region has many features characteristic of northern Indiana. There yet remain a few small lakes, areas of muck are of common occurrence, here and there big boulders dot the hillsides, and in many localities wind-drifted sand mantles the clayey drift in that exceedingly erratic fashion which makes the mapping of the soils a well nigh impossible task.

The valley of the Eel River is the boundary between these two divers sections of the county. A glance at the map suggests the Wabash, only a few miles to the south, as the dividing line, but this is not the case. The Wabash Valley is essentially a trench, cut almost straight across the county from east to west, its bluff-like sides rising 60 to 70 feet above the valley floor. They are very abrupt in most places, and from their crests the upland plain immediately sets in. Along the Eel, the slopes are more gradual, and much of this valley is a series of uneven, sandy terraces. No doubt the basal materials in the Eel Valley would prove, on more thorough exploration, to be similar to those in the Wabash trough, but the surface features are quite different.

The largest of the Wabash terraces within the territory under consideration is the one whose upper end affords such fine residential sites within the city of Peru. Its southern margin is a steep, stony slope, 20 or 30 feet high, while its northern border is not quite as well defined, and overlooks a wide muck bed extending to the foot of the hills on the north. Remnants of this same terrace occur further up the valley, ranging from gravely mounds of a few acres to two benches of several hundred acres each. On all these larger terraces, leaching and

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oxidation have extended to a depth of three or four feet, and a silty soil has developed.

An interesting feature of the two small terraces just mentioned is a narrow rim of sand, occupying part of the extreme northern margin of each. It is 8 or 10 feet high—where best developed—and only a few rods wide at the base. That they are local dunes can hardly be doubted, but at what period in the valley's history were they formed? The surrounding alluvium, both that of recent origin and that which has begun to show the effect of atmospheric agencies, is very silty and generally deficient in sand. Are these valley dunes related to those of the uplands? Do they all represent a period when climatic conditions were different from those of the present?

South of the Wabash Valley and also on the uplands between the Wabash and Eel rivers, the superficial member of the glacial deposits is a heavy, silty clay, light colored, dense and highly calcareous. There are few boulders, and the rather sparse glacial rubble that has accumulated on eroded slopes represents the coarse residue from a very considerable mass of material. The total proportion of constituents coarser than sand seems to be very small. The weathered surface, the "solum" of the soil surveyors, is commonly less than 40 inches on the smoother areas and rarely exceeds 50 or 60 inches on slopes.

North of the Eel Valley the till seems to carry a slightly higher percentage of coarse material, but the more vigorous denudation in this region must be considered in this connection.

Since all the present stream valleys were originally lines of glacial discharge with consequent accumulations of sand and gravel, these materials are almost everywhere found beneath a thin covering of recent alluvium. Some of the gravel pits along Pike Creek are 40 feet deep with but little or no inter-bedded clay. In places, however, on this and other small streams thin layers of stiff, heavy calcareous clay, evidently water laid, have been reported. These pits have all yielded more or less forest debris in the shape of lignitized logs and masses of well preserved leaves.

On Deer Creek, both above and below State Road 31, there is a gravely layer, underlying several feet of recent alluvium, and resting upon blue clay. This gravel stratum is rich in vegetable remains, some of which are nuts from walnut and white walnut trees, small thin-shelled hickories, and many unidentified fruit pods. The abundance and variety of leaves from deciduous trees would no doubt afford many interesting results if the paleo-botanist should give them his attention.

In the museum in the Court House at Peru may be seen a number of bones of a very large mastodon from a peat deposit in Perry Township. The same locality also yielded the skull of a musk ox, and a number of mammalian bones and horns have been taken from the gravel pits and stream beds in other parts of the county.

FOSSILS FROM THE MANCOS-DAKOTA-TUNUNK FORMATION IN THE VICINITY OF STEAMBOAT, ARIZONA.

ALBERT B. REAGAN, Cornfields, Ganado, Arizona.

The invertebrate fossils from the Mancos-Dakota-Tununk formation, collected in the vicinity of Steamboat, Arizona, and identified by the writer, as given below, show the formation to be transitional between the true Dakota and the overlying Colorado group. Many of the fossils occur in both divisions, but reach their maximum development in the Colorado. Again, the fossils that run through the whole Dakota series here are small in size in the lower beds and increase in size upward, apparently indicating that they began their life-circle in the lower beds.

VERTEBRATE—PISCES.

Ichthyodectes ctenodon Cope(?). (Fig. 2.) Proc. Amer. Phil. Soc., Nov., 1870; Hayden's Geol. Surv. Wyoming, etc., 1871, p. 421, part; U. S. Geol. Surv. of Terr., vol. II, 1875, pp. 207-8, pl. XLVI, figs. 1-4. (Figure 4 is a cervical vertebra like the ones here figured.)

The specimen described by Cope was found by Professor Mudge on the North Fork of the Smoky Hill River and he states that the species is common in many other localities. The writer's specimen was found in a coal mine at Steamboat, Arizona, in a clayey rock at the base of the Dakota. It was found by an Indian workman who called the mine owner's attention to it, and he saved the specimen for the writer, after the Indian had taken out some of the vertebrae for "medicine." Only cervical vertebrae were obtained but these are apparently identical with cervical vertebrae figured by Cope on the plate cited above as belonging to this species.

INVERTEBRATE—RADIATA.

Coral sp. (Fig. 1.) A coral, whose size and form (much reduced) are shown by the figure, was found in the beds under consideration. The whole of the interior of the corallum has decayed, therefore the genus cannot be determined. Locality: Near Hogay Ruin (No. 99), Steamboat, Arizona.

LAMELLIBRANCHIATA—MONOMYARIA—OSTREIDAE.

Ostrea (Gryphaea?) patina Meek and Hayden. (Figs. 15-26.) Proc. Acad. Nat. Sci., Phila., p. 277; U. S. Geol. Surv. Terr., 1876, Vol. IX, pp. 16-19, pl. 10, figs. 2a, b, d; a, b (bis), and e, f; also pl. 11; White, 4th Ann. Rept. U. S. Geol. Surv. ("Fossils Ostreidae of North America"), p. 278, pl. XLVII, figs. 4-6; Schuchert-Gregory, Geol. of the Navajo country (U. S. Geol. Surv., Professional paper 93, 1917), p. 74.

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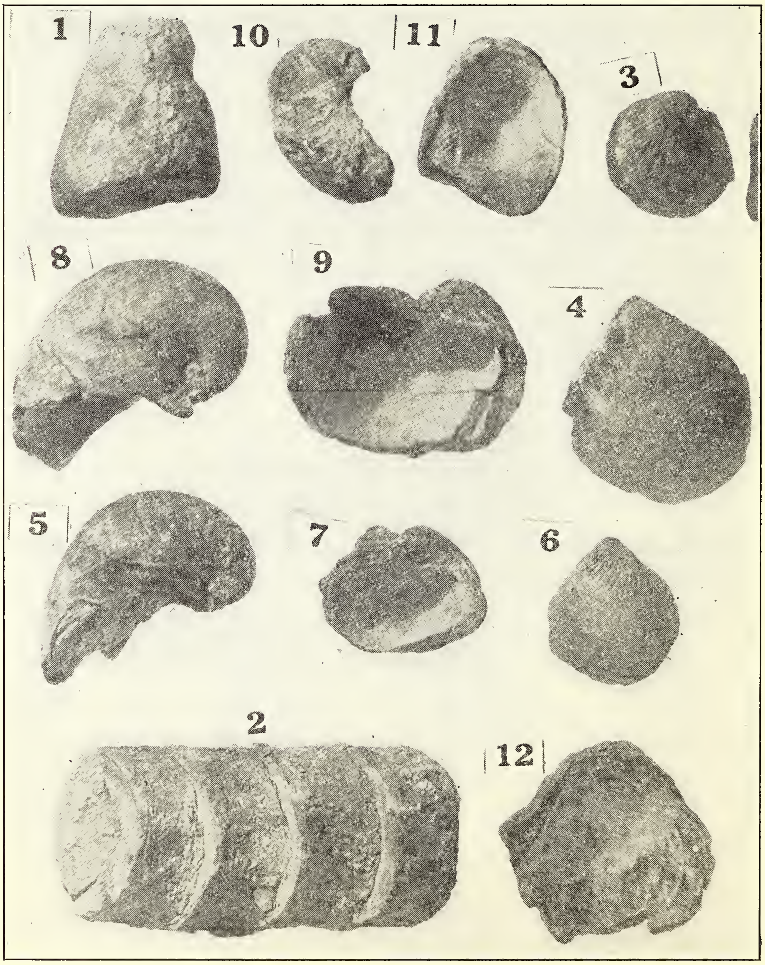
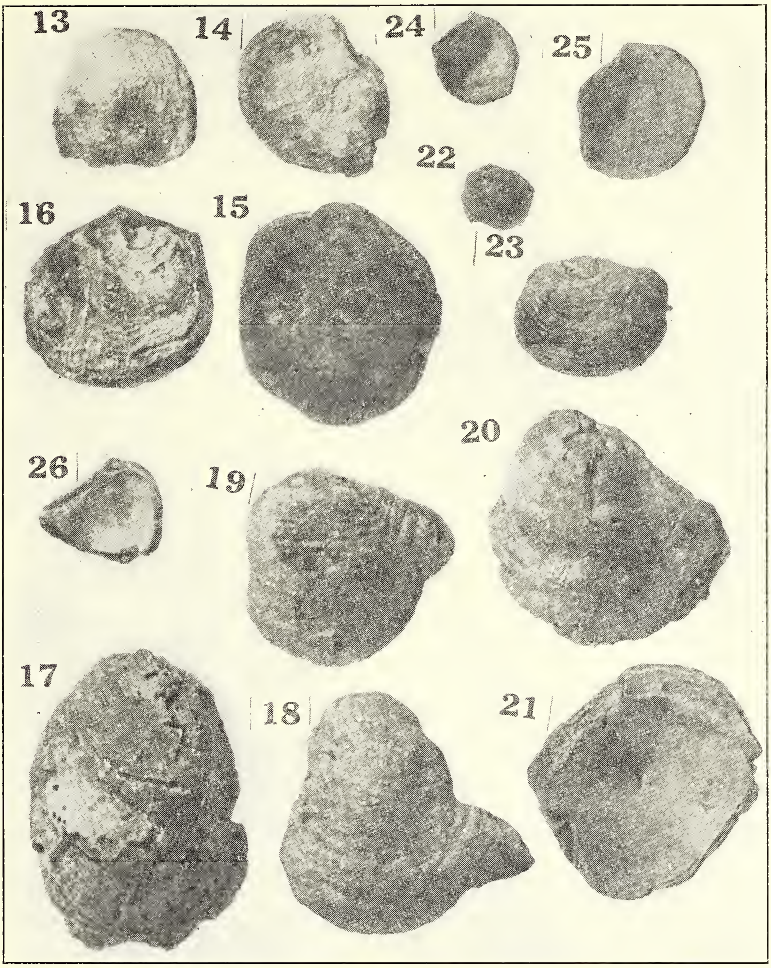
Ostrea prudentia White(?), 1876, U. S. Geol. Surv. West 100th Meridian, vol. IV, p. 181, pl. 14, figs. 2a-b; 1884, 4th Ann. Rept. U. S. Geol. Surv., p. 299, pl. 40, figs. 5 and 6.

This is a very variable species, resembling the Gryphaeas very much and especially *Gryphaea vesicularis*. A description of the more regular shells here follows:



Figs. 1-12. 1, *Coral* sp.; 2, *Ichthyoaectes ctenodon* Cope (?), cervical vertebrae; 3-7, *Exogyra columbella* Meek. 3, outside of upper valve looking down on the whorl, which shows radiating lines, characteristic of the species, 4, looking across back and showing radiating lines, 5, side view of broken specimen, showing the striated beak-part of shell, 6, young specimen showing radiating lines near beak, 7, inside view showing muscular impression; 8-9, *E. laeviuscula* Roem. 8, inside view of much broken valve, showing whorl, 9, inside view of much broken valve showing muscular impression; 10-12, *Gryphaea newberryi* Stant. 10, side view of complete, undistorted lower valve, 11 and 12, inside views of lower valve. These specimens except 2, from transitional Dakota-Mancos series at Steamboat, Ariz. Number 2 from bank of Dakota formation at same locality.



Figs. 13-26. 13, *Exogyra suborbiculata* Lamark, outside view of the upper valve showing lines of growth and, 14, inside view of a similar valve of another specimen of same species; 15-26, *Ostrea patina* M. and H. 15, inside view of the upper flattish valve showing muscular impression, 16, a reverse view of a similar valve, 17-20, outside views of distorted, adult lower valves, 21 and 24-26 inside views of the larger valves, 22-23, outside of the large valves from rear. All of the above from the transitional Dakota-Mancos series at Steamboat, Ariz., obtained from a stratum that caps the mesa west of Steamboat rock.

Shell almost circular to subovate (some shells are irregularly subovate to elongate-ovate), a little oblique, some compressed. Upper valve concave above, rather thin, but thickened near the beak where it is truncate; area rather broad, triangular, standing nearly at right angles to the plane of the shell, and broadly depressed in the middle; lateral margins near the area more or less constricted,—the valve resembling a little shield or a painter's palette in shape. Lower valve thicker to rather thick, quite a bit concave; latter margins near the beak usually considerably thickened and distinctly lamello-striate; beak triangular, broadly depressed to much compressed, extending beyond the cardinal border and slightly curved upward at the front, without any visible scar of attachment, often very much distorted; area comparatively small, broad, triangular, having a wide, shallow depression along the middle. Muscular impression is nearly circular to triangular oval, varying much with different shells, moderately distinct, located near the left side and about halfway between the beaks and the postero-ventral extremity. Surface marked by more or less strong lines of growth. Length and breadth of a medium sized specimen, each about 2.50 inches; concavity of lower valve, from .50 to .75 inch.

The above description is of the average shells, on both sides of which there is a wide range of variation and even the above would almost be a good description of *Gryphaea vesicularis* Lam. (*G. convexa* S. and M.); yet they present well-marked and constant differences from all the varieties of that variable species. The lower valve of the shells at hand is never so ventricose as that of *G. vesicularis* or its common varieties. It also differs from that species in its being auriculate at the extremities and in its having its cardinal margin sloping from the beaks instead of being extended in a right line. Furthermore, its hinge prominence is never nearly so gibbous nor so much incurved as is usual in that species.

It agrees with *G. mutabilis* Morton (which is now regarded by most paleontologists as a marked variety of *G. vesicularis*) in its under valve being rather shallow and in its having a compressed beak; but it differs from that species in that it has its cardinal margin more or less straight, in its extremities being distinctly articulate and in its smaller valve being more strongly marked with radiating lines than the more convex varieties of *G. vesicularis*.

Some of the variable forms of this species differ from the type species only in having the umbo of the lower valve somewhat distorted by the scar of attachment. Others show still more and more distinct marks of attachment, become more ovate or elongate in form, and have the left anal margin near the beak more and more sinuous. These changes continue till the shells differ widely from the typical forms. It would seem that even *Ostrea inornata* M. and M. might be one of the elongated varieties of this shell, the principal difference being that it is a longer shell, it being irregularly subovate to elongate-ovate, oblique, narrow near the beaks, somewhat compressed, and abruptly widened by an expansion of the left border near the other extremity.

Some of the other, more prominent varieties of this species, as shown by the shells at hand, are here given:

Variety A.—Shell nearly round, but quite variable and irregular in shape, oblique, narrow near the beaks, and abruptly widened by an expansion of the left border near the other extremity; umbo of under valve distorted and curved upward; border of left side of valve thin and quite sinuous, but thickened on the right side of the beak; area of upper valve inclined obliquely toward the cardinal extremity. This variety resembles *O. inornata* nearly as much as it does *O. patina*, being less in length than the former and this apparently being the only difference. As all the shells were collected in an area less than 200 feet square and all from the same stratum it would seem best, however, to consider them as *O. patina.* Length of several shells examined, 3 to 3.50 inches; breadth, an average of about 2.40 inches; breadth near beaks, 1.10 to 1.30 inches.

Variety B.—Shell broadly oval; beak of under valve much distorted; area usually or nearly obliterated by scar of attachment; anterior and anterio-ventral border forming an almost semi-circular curve, while the anal side has a broad sinus near the hinge. Length and breadth, each about 3.00 inches for adults; concavity of under valve a little less than an inch.

Variety C.—Shell ovate, narrow near the beaks, much wider toward the extremities; beak of lower valve usually distorted on the left side by the scar of attachment, usually curving slightly upward; margin of shell thin, except near the right side of the beak, where it is noticeably thickened. Length, about 3.00 inches; breadth from 2.10 to 2.40 inches; concavity of under valve, an average of about .40 inches.

Locality and Position: Two hundred miles above the mouth of Milk River on the Missouri; in Fort Pierre group, or formation No. 4 of the Cretacic series (Meek); at Tuba coal mine in the Mancos shales (Gregory-Schuchert); at Steamboat, Apache Co., Arizona, in the Dakota (and Tununk) sandstone (Reagan). The specimens figured are from the latter location. Specimens were obtained from the base of the series as presented at Steamboat, also from the middle and from the top of the series in the vicinity of Hogay Ruin (No. 99), the fossils from the latter place being those described and figured.

Gryphaea newberryi Stanton (Figs. 10-12). *G. pitcheri* White, 1876, U. S. Geog. and Geol. Surv. West 100th Meridian, vol. IV, p. 171, pl. 17, figs. 1a-f; *G. pitcheri* N. and M., 1876, in Macomb's Exploring Expd., from Santa Fe to Junct. of Grand and Green Rivers; nec *G. pitcheri* Morton, 1834, Synopsis Org. Rem. Cret. Group, p. 55, pl. 15, fig. 9; *G. newberryi* Stanton, 1893, U. S. Geol. Surv. Bull. 106, pp. 60-62, pl. V, figs. 1-5. It is this species that Newberry called *G. pitcheri* and *G. pitcheri var navia.*[1] Mr. Gregory[2] reports it from Red Wash, near the Carrizo Mountains in the lower part of the Mancos. The writer's specimens are both from the base and the upper part of the Dakota and Dakota-Mancos transition. (Tununk) area as represented at Steamboat, in the vicinity of Hogay Ruin (No. 99).

Adult shell moderately large, very variable in shape, generally irregularly subovate in marginal outline, sometimes shorter than broad, but usually much longer than broad. Under valve spacious-roomy, boat-shaped, bow-shaped, more or less lobed, the rear lobe often wing like; shell rather thick; umbo conspicuous, large and incurved, though sometimes short and flattened; scar of attachment small or wanting; surface usually marked by concentric lines of growth, at other times smooth. Upper valve nearly flat, shield shaped, usually quite thin except where thickened in the umbonal region; hinge line straight; area distinct; ligamental groove small; inner surface more or less crenulated at the lateral edge, otherwise smooth; outer surface marked by concentric, overlapping lines of growth, and sometimes by faint radiating striae. Average length from umbo to basal margin, about 1.50 inches.

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[1] Newberry, J. S., Ives Expedition, pp. 80-96, 117-132.

[2] Loc. Cit., p. 74.

The collection which the writer furnished Stanford University contains numerous examples of this widely known species, none of which, however, are of so large a size as are some of those figured by Conrad, Roemer, and others. It might further be added that in this collection there are two distinct varietal types of this species. One resembles *G. vesicularis* and the other *G. pitcheri*, var. *navia*.

Position and Location: Lower part of the Upper Cretacic shales in southwestern Utah and adjacent portions of Colorado, Arizona, and New Mexico (Stanton); 350 feet above the base of the Cretacic in Upper Kanab valley, Utah (White, Walcott); Mancos, Colorado, from shales overlying sandstone referable to the Dakota formation (Stanton); Lower Cretacic strata at the Hopi village of Shongnovi (which species he called *G. pitcheri* and var. *navia* (Newberry); at the base of the Dakota, three miles east of Steamboat, Arizona, at the top of the Dakota near Hogay Ruin (No. 99), where it is abundant; at the base of the Mancos and top of the Dakota, one mile west of Salina Springs and in the Tununk formation in the transitional Dakota-Mancos series at Steamboat, Arizona (Reagan).

Exogyra suborbiculata Lamark (sp.) (Figs. 13-14). *Gryphaea suborbiculata* Lamark, 1802, Systeme des Animaux sans Vertebres, p. 398; *G. ratisbonensis* Sch., 1913, Minn. Tasch., vol. VII, p. 105; *G. columba* Lamark, 1919, Op. cit., vol. VI, p. 198; *Ostrea ratisbonensis* Coquand, 1869 (with full synonymy), Monog. Gen. Ostrea, Terr. Cret., p. 121; *Exogyra suborbiculata* Atoliczka, 1871, Cret. Pelecypoda of Southern India, p. 462; *Exogyra suborbiculata* (Lamark) Stanton, 1893, U. S. Geol. Surv. Bull. 106, pp. 62-63, pl. V, fig. 6; pl. VI, figs. 1 and 2; pl. VIII, fig. 1. Several upper valves of this species were found in the lower division of the Dakota at Steamboat. Shell large, thin, from almost circular to subovate in outline. Lower valve quite convex; umbonal region narrow but prominent; beaks small, coiled, somewhat separated from the body of the shell; a distinct depression extends from the umbonal region to the posterior basal margin. Surface marked by lines of growth, otherwise smooth. Upper valve nearly flat, with coiled beak and marked by faint to distinct concentric ridges near the margin. Average length from base to beak, about 3.25 inches; greatest transverse breadth 3.13 inches; convexity, about 1.63 inches.

This species much resembles the European species *Ostrea* or *Exogyra columba*. It is also reported as occurring throughout Europe and in Southern India in the Middle Cretacic (Cenomanian and Turonian). It is also said to be best developed in the zone with *Inoceramus labiatus*. It might also be added that *Exogyra columbella* Meek may prove to be only the young or a variety of this species, though it seems to favor *E. laeviuscula* more, as will be noted later.

Position and Locality: In the Pugnellus sandstone near Malchite postoffice and Poison Canyon, in Huerfano Park, and at about the same horizon at Rattlesnake butte and on the Arkansas River, 20 miles above Pueblo, Colorado (Stanton); in the lower division of the Dakota in the vicinity of Steamboat, Arizona (Reagan).

Exogyra columbella Meek (Figs. 3-7). *E. costata* var. *fluminis* White, 1876, U. S. Geog. and Geol. Surv. West 100th Meridian, vol. IV, p. 174, pl. 17, figs. 3a-d; *E. columbella* Meek, 1876, Macomb's Expl. Expdn. from Santa Fe to junction of Grand and Green rivers, p. 124, pl. 1, figs. 3a-d; White, 1884, 4th Ann. Rept., U. S. Geol. Surv., p. 304, pl. 55, figs. 5 and 6; Stanton, 1893, U. S. Geol. Surv. Bull. 106, pp. 63-64, pl. VIII, figs. 2, 3, 4. This species is found throughout the Dakota series but is most abundant at the top near Hogay Ruin (No. 99). It is also found abundantly in the Tununk (Dakota-Mancos transition series) both at Steamboat and at Salina Springs.

Professor Meek's description of the species is, in part, as follows: "Shell small, rather thin, ovate; posterior side forming a semi-oval curve fromthe umbo to the ventral edge; anterior side rounded below the beak; ventral margin rounded. Lower valve convex, the most gibbous part sometimes forming an obtuse umbonal prominence, which is not separated from the front by a sulcus; beak slender, pointed, and distinctly coiled to the left; surface ornamented by small, but distinct, rather regular, radiating costae, which bifurcate along the umbonal ridge; marks of growth rather obscure. Upper valve flat, oval, apparently smooth, or only having obscure lines of growth."

This species closely resembles *E. laeviuscula* Roemer, but its shells are more oval in form and have a less distinctly spiral beak than the forms described by Roemer or those which the writer has in the collection at Stanford University. It also differs in its having the under valve always marked by regular radiating costae, while in the other species the costae are usually wanting or if present at all they are generally broad plications. Its shells are also thinner and less robust than those of *E. laeviuscula.* On the other hand, it closely resembles *E. columba* (Anim. sans Vert. VI, 198), though it is a much smaller species. It may prove to be the young of *E. laeviuscula,* or *E. suborbiculata,* as previously pointed out, the weight, at present, being in favor of its being the young of the former.

At times the surface of the larger valve, to about the middle of the shell from the beak, also shows some indistinct, flattish, rounded off, radiating folds, and especially are they noticed as such among smaller, younger specimens.

From the above, based on a comparison of the shells, some 40 in number, which the writer has in his possession, and the literature which he has at hand, it would appear that the species given as *E. columbella* should be considered as *E. laeviuscula.*

Position and Locality: From the Lower Cretacic of Dr. Newberry's New Mexican section at Covero, New Mexico, and from the base of the Middle Cretacic of the same section at Galisteo, and in the Sierra Abajo. The specimens described by White came from the east bank of the Rio Puerco, six miles below Casa Salazar, New Mexico, and it has also been collected in the Lower Cross Timber (=Dakota) sands and in the Eagle Ford (=Colorado group) shales of Texas (Stanton). In places this formation (Dakota) is lacking altogether (in the Navajo country) and shale carrying *Exogyra columbella* Meek ? lies directly upon the McElmo formation (Gregory). Dr. Gregory also reports this species being found in the Mancos shales in a three-foot bed of coquina 60 feet above the base of the formation at Lalomi Point, also at Round Top Butte, and in the Hopi volcanic field. The writer found it in the Dakota, principally at the top of the formation, where it might be just as appropriately considered at the base of the Mancos. (This transitional section is designated as Tununk formation in this paper.)

Exogyra laeviuscula Roemer (Figs. 8-12), 1852, Kreidebildungen von Texas, p. 70, pl. 9, figs. 3a-c; Conrad, 1857, U. S. & Mex. Bound. Surv., p. 154, pl. 7, figs. 4a, b; White, 1876, U. S. Geog. & Geol. Surv. West 100th Meridian, p. 173, pl. 17, figs. 2a-d; 1884, 4th Ann. Rept., U. S. Geol. Surv., p. 305, pl. 52, figs. 3, 4, 5; Stanton, 1893, U. S. Geol. Surv. Bull. 106, pp. 64-65, pl. VIII, figs. 5 and 6; *Ostrea ferdinandi* Coquand, 1889, Monog. Gen. Ostrea, Terr. Cret. p. 33; *E. ponderosa* Hill, 1889, Check List Cret. Invert. Fossils of Texas, p. 6. Specimens of this species are very common in the Dakota near the top of the formation, being very abundant in the vicinity of Hogay Ruin (No. 99), the writer collected specimens even from the base of the formation about three miles east of Steamboat store. They are always found associated with the characteristically marked shells of the *E. columbella* type.

Shell is of moderate size, is oval to semi-ovate in form and is high arched and suborbicular in marginal outline; test not massive. The larger valve is "puffed-up," almost hemispherically divided into two almost equal halves through the blunt, rounded-off, medium keel, which slopes downward toward the border with approximately equal inclination; but more prominent near the beak. On some specimens this feature is wholly wanting. The umbo is small, developing into a rapidly tapering, rolled-in, closely incurved spire which is outstanding, sometimes nearly free but not so free as those of the Texas species figured by Roemer, rarely in-grown, making about two volutions, often very closely curved, giving the posterior side an umblical character, sometimes having a very small scar of attachment; but never is the attachment so large that by it, as in other kinds of the genus, the whirl is wholly atrophied, and the form of the shell made generally irregular thereby. However, it is usually without such scar, and always quite symmetrical, or at least not distorted, as the beak often is in other species of the same genus; periphery of its curve usually extending beyond the hinge line, but sometimes not; the indistinct hinge is often wanting. The outside of the valve is smooth, only showing up to the transverse-middle circumference-line some irregular, somewhat squamous, projecting, increasing striation-lines. The border of the valve is almost round, thin, fragile. The smaller valve is nearly flat or slightly and somewhat irregularly concave, suborbicular to palette-shape in outline; surface marked by faint to almost indistinct lines of growth, otherwise smooth. Diameter of average examples in the collection about 2 inches; transverse diameter from 1.50 to 1.75 inches; depth of larger valve a little less to a little over an inch.

This and allied species have been the subject of much discussion in the past. R. T. Hill maintains that the shells which are considered as of the species *E. laeviuscula* are young individuals of *E. ponderosa*. The fact that they occur together would cause one to suspect their identity. However, even when the shells are of the same size, those described under *E. ponderosa* are more angular in the umbonal region, less circular in outline and not so smooth as those described under *E. laeviuscula*. However, the writer would conclude that *E. columbella* Meek and *E. laeviuscula* Roemer are one and the same, as is probably *E. suborbiculata* Lamark and that they are probably the more or less young individuals of *E. ponderosa*, as was Hill's conclusion, *E. ponderosa* being very similar to *E. laeviuscula*, only very much larger, and probably the maturer shell.

Position and Locality: Strata of the Cretacic period, Linear Plateau, southwestern Utah (Stanton); Cretacic from near San Antonio, Texas (Roemer); 60 feet above the base of the Mancos at Lolomi Point and in the base of the Mancos on Navajo Mountain in the Navajo country, Arizona (Gregory); in the Dakota at Steamboat, Arizona, but found principally at the top of the series on the transitional line (in the Tununk formation) between the Dakota and the Mancos in the vicinity of Hogay Ruin (No. 99) (Reagan).

PROPER MOTION OF WEISSE XXIII 175.

W. A. COGSHALL.

This star is also known as Beta 182 and was measured as a double star as early as 1876. Its large proper motion was recognized soon after. There are two small stars near the bright pair from which the proper motion may be found—only the more distant one is bright enough to be seen with any degree of certainty in our 12-inch telescope.

I measured the distance and position angle of this star with respect to the bright pair in November of 1901, 1902 and 1903 and again in 1925, thus getting a determination of its motion over a period of 24 years.

In 1901 the position angle was 160°.1 and the distance 155″.99. The mean of the 1925 measures give, angle 162°.1, distance 131″.30. This gives a total motion for the 24 years of 30″.44, or 1″.38 per year, in angle 206°.6. Burnham gives 1″.30 in angle 200°.

Observations were started on this star with the hope of finally deriving a parallax. This idea was abandoned in view of the limited equipment and low declination of the star, but its parallax has been accurately determined by Mitchell at the University of Virginia.

This star has a parallax of 0″.028 and from this we may get an idea of its velocity through space, or at least may get a value of the lower limit of this velocity. At a distance corresponding to a parallax of 0″.03, an annual motion of 1″.38 means that the star must travel at least forty-six times the distance from the sun to the earth. In order to do this it must have a velocity of 138 miles per second.

In case the star is either approaching the earth or receding from it, this value would have to be increased, and it might be anything larger than the above value. As far as I know its radial velocity has not been determined.

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A NEW TYPE OF SOUND AMPLIFYING HORN.

Arthur L. Foley, Indiana University.

A vibrating tuning fork held in the hand produces little sound. The volume of the air thrown into vibration by the prongs of the fork is small. When one places the handle of the fork against a table top or anything else that can be set into vibration by the fork the intensity of the sound is increased. The fork has been forced to work "harder" (to spend its energy more rapidly) in causing the vibrations of the table. The table top does not of itself produce any sound. It merely forces the fork to produce more.

People generally do not seem to understand that the principle stated above applies to all kinds of sound amplifying devices, including phonograph and radio horns and cone loud speakers, even though the action of the latter and the table top amplification is practically identical. The case of the horn is a little more difficult to visualize. When the diaphragm of the phonograph reproducer or radio receiving unit vibrates in the open the resistance offered by the free air is so small that the diaphragm dissipates energy very slowly. However, if the air about the diaphragm be confined, as by a horn, it offers more resistance and the diaphragm is called upon to do more work, the rate being dependent upon various factors, amongst which are the length, shape and cross section of the air column in the horn. The maximum amplification results when the horn dimensions are such that the diaphragm is called upon to work at its greatest possible rate. Like an electric motor, for the highest efficiency it should be neither under nor over-loaded.

It is well known that an air column has more or less selective resonance and consequently selective tone amplification. The trombone player produces the particular tone he wants by adjusting the length of the air column. A flute player does the same thing. In one case the air column is curved, in the other, straight. The curves in the trombone are so gentle that the sound waves follow the tortuous path through the horn without suffering very much internal reflection. But if there were an abrupt turn, more or less of the sound wave energy would be reflected backwards at that turn. This would tend to set up a stationary vibration in the horn of a wave length different from that which is produced by reflection at the far end of the horn. The net result would be that the intensity of the resonance due to the stationary waves set up between the two extreme ends of the horn would be diminished, and the intensity of the sound corresponding to the stationary vibrations between the abrupt turn and the end of the horn would be increased. By the use of this principle in the design of a horn, it may be made resonant to a greater number of tones than if the axis of the horn were straight.

If the walls of a horn are smooth and rigid, the quality and degree of resonance is independent of the material of which they are made.

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But inasmuch as most materials do not possess these characteristics, considerable loss of sound energy may result from their use. But if the walls of the horn be made of a material that approaches what we call perfect elasticity, they may absorb large quantities of sound energy without decreasing the intensity of the total output. The energy which they absorb throws them into vibration and they in turn throw in vibration the air with which they are in contact—an action similar to the table top experiment above mentioned. The writer has made use of this principle, as well as that of internal reflections, in the design of the horn briefly described as follows:

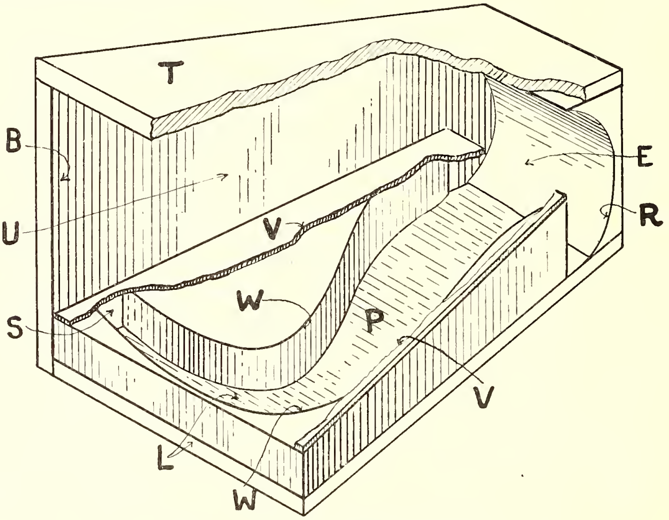

Fig. 1. Sound Amplifying Horn.

Figure 1 is a perspective drawing of a horn in which the near side and most of the top T and the partition V, hereafter called the vibrator, have been cut away to show the details of the interior. The curved baffles W form the side walls, while the lower wall of the horn L and the vibrator board function as the other two walls of a curved sound passage P. Sound enters the passage at the small end S and on emergence at the large end E strikes a curved reflecting surface R which reflects much of it into the upper passage U between the vibrator and horn top from which it emerges at the bell end of the horn B. But not all the energy passing through P is reflected at once into U. A portion of it (re-entrant) is reflected back into P, thus tending to set up stationary vibrations in P corresponding to waves of higher frequency than the vibrations set up between the extreme ends of the horn S and B. Likewise, some of the energy reflected back into U from the open end B is again reflected at R into U, causing stationary waves between B and R. Both sections or segments of the horn therefore have their own resonance frequencies which by properly designing the horn, can be made different from one another and from the resonance frequency of the horn as a whole.

We have spoken of the resonance frequency of P as if it were a single and definite frequency. It would be so if P were straight or but gradually curved. But with the rather sharp curves which the horn actually has (much sharper than the drawing suggests) sound entering P is variously and multiply reflected from the side walls before reaching the reflector R. The actual distance the sound must travel in passing from S to R is thus considerably increased and as a consequence the pitch of the lowest resonant tone is correspondingly lowered. The net result is that the resonance of P for a particular frequency is reduced while the range of frequencies which this segment of the horn amplifies is correspondingly broadened.

The cross section area of the passage P being relatively small the sound waves (compressions and rarefactions of the enclosed air) tend strongly to produce vibrations of the walls of the passage. The two side walls W and the lower wall L are made massive and stiff. The upper wall, called the vibrator, V, is of thin elastic material and is of such a shape that it can readily vibrate in unison with the sound waves passing underneath. The vibration of V sets up waves which pass across the horn (transverse to the horn's axis) where they are again transversely reflected by the top T to the vibrator board. Several such reflections may take place before the waves finally emerge at B. This multiple reflection again greatly increases the effective length of the horn and increases the frequency range of its resonance. Note that the wider end of the vibrator V is at the rear end of U and that it naturally vibrates at a lower rate than the narrow portion of the vibrator near B. The lower pitched waves produced at the rear must travel farther before emergence than the higher pitched waves generated near B, in both cases a necessary condition for amplification. It should be noticed that the vibrator board, as a sound amplifier, functions much as the disk of a fixed edge cone.

It may be seen that the horn described is not a simple air volume resonator, but that it is a combination in a single instrument of a series of air resonators, a reflex horn, a straight horn, a curved horn, a re-entrant horn, and a resonating diaphragm or sounding board, and that it makes use of both multiple and cross resonance, all in the effort to secure as nearly as possible uniform tone amplification. Such a horn (designed as a radio loud speaker) 12 inches long and only 8 by 8 inches outside at the larger end gives sound volume and quality quite comparable to that produced by any other horn the author ever tested, regardless of size.

Within the last year or so many manufacturers, in order to satisfy what the writer believes is but a passing mood, have gone to the extreme in designing phonograph and radio horns to accentuate the lower tones. The "empty barrel" tones are over amplified, usually at the expense of the higher tones. Remembering that even a low tone has many *higher harmonics that must be amplified just as strongly as the fundamental* in order to give the tone its true quality, it is evident that over emphasis of tones of low pitch (or of any pitch) is something to be avoided. In the opinion of the writer that amplifier is best which most nearly reproduces the original sound, whatever be its character.

THE EFFECT OF A DISSOLVING SALT ON THE PITCH OF A VESSEL PARTIALLY FILLED WITH WATER.

ARTHUR L. FOLEY, INDIANA UNIVERSITY..

While dissolving some sodium phosphate in a glass tumbler about two-thirds full of water it was observed that the sound produced by striking a spoon against the glass was at first considerably lowered in pitch, and that the tone produced gradually rose in frequency as the solution proceeded, returning in a few seconds to practically the same pitch the vessel had before the salt was added. Of the several factors upon which the pitch of the tumbler depends all are constant in this experiment except the depth of the water and the elasticity and density of the solution. That the pitch change was not due to change of depth, or largely to change of density was proved by the fact that it did not occur with all salts (chloride of tin, for instance), or when fine sand was stirred in the water. It would appear, therefore, that the change was due chiefly to a change in the elasticity of the solution during the time the salt was dissolving, and during solution only. This conclusion was strengthened by the fact that the pitch change seemed to be roughly proportional to the amount of chemical reaction taking place during solution. It was particularly marked in the case of those salts in which more or less gas was evolved when dissolving. A small quantity of effervescent sodium phosphate mixed with the non-effervescent greatly increased the pitch change. Similar results were obtained when other containing vessels were used, such as tin cans and glass bottles. However, in the case of bottles with a long neck the effect is much less striking.

Inasmuch as wave velocity depends on the elasticity of the medium in which the waves are traveling, one might expect a considerable change in the velocity of sound through a fluid in which a salt is dissolving, and possibly in any solution in which chemical action is taking place. Experiments in this field will be made later.

The chief object in presenting this topic to the Academy is to call attention to the fact that, if one will but look for them, he will find problems for study and investigation on every hand. The writer's wife and his secretary years ago had observed the pitch change when soda was stirred in a bottle of sour milk. Doubtless millions of others have made similar observations. But to the writer's knowledge no attempt has been made, heretofore, to answer the question "why?" There are plenty of questions which Indiana high school teachers having little or no laboratory equipment could investigate if they willed to do so.

May not the physics program of the Indiana Academy of Science next year include the names of several who "will to do so"?

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MEASUREMENT OF CONDENSER AND COIL RESISTANCES BY THE DIFFERENTIAL THERMOMETER METHOD.

R. R. Ramsey, Indiana University.

The method of measuring the high frequency resistance of wire by means of the differential thermometer is due to J. A. Fleming (Proc. Phys. Soc. London, 23, p. 103. 1911).

In this method the heat developed in a wire by a known radio frequency current is compared to the heat developed in a similar wire by a direct current. The accuracy of the method is not very great but it is the only method by which an experimental comparison can be made. The high frequency resistance of a given wire is usually calculated by a theoretical formula which has been found to give results agreeing with the experimental method. Radio frequency resistance boxes are constructed of small wire, the resistance of which according to the formula is the same as the D. C. resistance of the wire. It is usual to measure the resistance of a circuit by means of the radio frequency resistance boxes.

A radio frequency circuit consists of a coil and a condenser. It is comparatively easy to measure the resistance of the circuit but to separate the resistance of the coil from the resistance of the condenser is a difficult matter. It has been customary to assume the resistance of the condenser to be zero and to ascribe all the resistance of the circuit to the coil. The basis for this assumption is the fact that dielectric losses as measured at frequencies up to two or three thousand cycles are found to diminish with frequency. When calculated for a frequency of a million cycles the losses are estimated to be almost zero.

Weyl and Harris (Inst. of Radio Eng., Proc. 13. 109, Feb. 1925) and Callis (Phil. Mag. 1, 428, Feb. 1926) have made measurements of the resistance (losses) in radio condensers at radio frequency and have found the losses to be considerable, the measured resistance being about one ohm at full capacity and as high as 20 ohms at small capacity.

Because these results were so large compared to the accepted values, I tried to find a check method. After considering various methods such as condensers in series and condensers in multiple and finding experimentally as well as theoretically that it was impossible to get a check, I finally resorted to the heat method. After the condenser was shown to have small resistance, the resistance of the coil was measured by the heat method. The coil resistance was found to be somewhat smaller than the values obtained by the usual method.

The condenser or coil was placed in one bulb of a differential air thermometer while a known D. C. resistance was placed in the second bulb. The thermometer was made of two pyrex glass beakers inverted

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and sealed to glass plates. Through each glass plate three holes were drilled. In two of these holes electrical connections were sealed, and in the third a glass tube was sealed. By connecting the glass tubes to a U-tube which contained a small amount of water, the relative pressure of the air in the beakers could be determined. Two T-tubes were placed above the U-tube, one under each beaker. By opening these T-tubes the pressure of the air in the beaker could be made equal to the pressure of the atmosphere.

The beakers were sealed to the glass plates with beeswax. At times there was some difficulty in getting the connection air tight. This was tested by noting whether the pressure became equal after a run. If there was evidence that one of the beakers leaked the result was discarded. The apparatus is shown in the diagram (fig. 1).

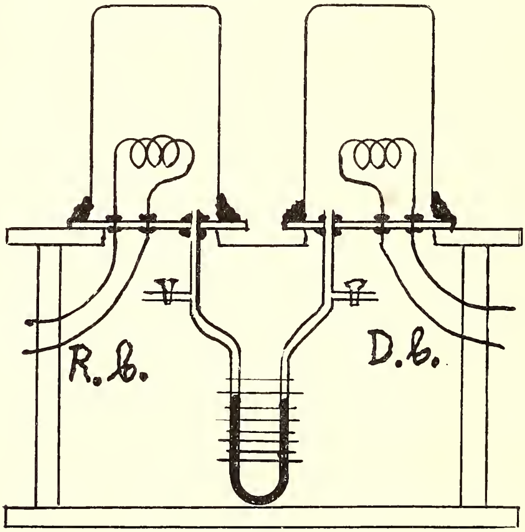

Fig. 1. Drawing showing the differential thermometer. The heat developed in the coil in the left hand beaker by the radio frequency current is balanced by the heat developed in the coil in the right hand beaker by the direct current. The equality of the height of the water in the U-tube indicates when equilibrium is established.

The coil or condenser under investigation was placed in one of the beakers and electrical connections were made with solder. In the second beaker a known D. C. resistance was placed and soldered to the electrical connections. It was found that when a coil was under investigation the best D. C. resistance to use was a coil which was an exact duplicate of the first coil. When the resistance of a condenser was being measured a short piece of "cromel" resistance wire, 3.4 ohms, was connected to the terminals in the D. C. beaker.

When making a measurement the procedure was as follows: The coil or condenser was placed in the beaker and connected in a high frequency circuit which was inductively connected to an oscillating circuit driven by a five-watt tube. The high frequency circuit was adjusted to the proper current value. The approximate value of the D. C. current was found and then the apparatus was left for some time to cool down to the temperature of the room, the two side T-tubes being open. In an hour or more the run proper was made. The side T-tubes were closed and the high frequency generator was started. The D. C. current was turned on and adjusted so as to keep the pressure in the two beakers equal, as indicated by the water in the U-tube. After some minutes when final equilibrium was obtained the two ammeters were read. The high frequency ammeter was a Westen 1.5 ampere thermo-ammeter which was correct for D. C. current and guaranteed by the maker to be accurate for 1500 kilocycle current. For small values of radio frequency current a General Radio 250 milliampere hot wire milliammeter was used. To measure D. C. current a Westen ammeter was placed in the circuit.

When thermal equilibrium is obtained the heat produced in one beaker is equal to the heat produced in the second beaker, assuming the thermal constants of the two beakers to be the same. Then $I^2R=i^2r$, where I and R refer to the current and resistance in the high frequency circuit, and i and r refer to the current and resistance in the D. C. circuit. Then we have the resistance of the radio frequency circuit is $R=(i^2r)/I^2$. Any dielectric losses, eddy current losses, or resistance losses will appear as heat. R, the resistance of the circuit, is the series resistance in the circuit which will produce the same heat as all these effects.

The accuracy of heat measurements is not as great as the accuracy of ordinary resistance measurements and the accuracy of these measurements is not as great as might be desired, but they are sufficiently accurate to indicate the approximate values and to settle the point in question.

When the coil was measured it was found that the resistance of the coil was less than the resistance of the circuit obtained by the resistance variation method. This result indicates that the condenser must have a resistance which can not be neglected. When the condenser was placed in the beaker the resistance was found to be very small—about 0.1 ohm—the capacity of the condenser being .00008 microfarads. This indicates that the heat generated in the circuit is less than the total energy of the circuit.

Table I gives the data taken using five different coils. A. C. resistance is the resistance of the coil measured by the resistance variation method, assuming the resistance of the condenser to be small. Resistance (Heat) is the resistance obtained by means of the calorimeter.

TABLE I. Resistance of Coils at 1,000 Kilocycles

Capacity of Condenser in Microfarads	D. C. Resistance	A. C. Resistance Resistance Variation Method	Resistance Heat Thermometer Method	Inductance in Microhenrys	Remarks
Coils of No. 20 Copper Wire, 30 Turns Each					
.00008	0.35	10.7	8.2	316	Two coils in series
.00028	0.35	8.3	7.3	91	Two coils series opposition
.00028	0.175	4.3	3.7	91	Single coil
Coil of No. 30 Copper Wire, 20 Turns					
.00020	9.6	19.4	11.5	127	Single coil
Coil of No. 40 Copper Wire, 14 Turns					
.00054	16.6	21.1	17.2	47	Single coil
Coil of No. 40 Copper Wire, 30 Turns					
.00009	34.3	52.5	36.6	282	Single coil

Each result given in the above table is the average of a number of separate determinations.

It will be noticed that in every case the resistance as measured by the heat method is less than that measured by the resistance variation method. The high frequency resistance of the coil was balanced against the D. C. resistance of a similar coil. As a check the connections were interchanged so as to test the equality of the thermal constants of the two bulbs. It was found that within the accuracy of the method there was no difference. Instead of a duplicate coil in some cases, the coil was checked against a short piece of resistance wire. These results agreed with the results obtained by using duplicate coils. Since the results obtained by the two methods check, it shows that the resistance of the condenser as given in the following table can be relied upon, as it was necessary to use unsymmetrical circuits when measuring the resistance of the condenser. To make the two circuits and bulbs as symmetrical as possible, a dummy condenser was placed in the D. C. side with the resistance wire in order to make the thermal capacity of the contents of the two bulbs equal.

In Table II given below, the average of a number of readings is given.

TABLE II. Resistance of a 11-Plate Condenser Set at .00008 m. f.
(About one-third maximum)

	300 Meters	80 Meters	40 Meters	27 Meters
Highest	.15 ohm	....	....	....
Lowest	.05 ohm	....	....	....
Mean	.098 ohm	.06 ohm	.04 ohm	.06 ohm

At first it was thought that the results for 80, 40 and 27 meters were too low since the ammeter in all probability read too high. Since then the ammeter has been calibrated at high frequency and found to be correct for $6x10^7$ cycles (5 meters). In the work at 300 meters it was necessary to keep the current at or below .8 ampere, since the potential became so high that an arc started between the plates of the condenser when the current was .9 ampere.

After these results were taken the condenser was compared with three others made by different firms and it was found that there was no appreciable difference between this condenser and the average condenser.

These results show that the resistance of a good radio condenser is not excessive and that the results of Weyl and Harris, and Callis are entirely too large. Their results must be explained in some other manner. The probable explanation is as follows: The calorimeter method measures the energy that remains in the pyrex glass beaker. Any energy radiated through the glass will not cause heat. Therefore, there must be an appreciable amount of energy radiated from an ordinary circuit. In other words, there is a certain amount of resistance in the circuit which can not be ascribed to either the condenser or to the coil.

A STRAIGHT LINE FREQUENCY AUDIO OSCILLATOR.

R. R. Ramsey, Indiana University.

In a laboratory there is need of a source of alternating current of varying frequency. This need was formerly met by using alternating generators in which the speed of the rotor could be changed. Frequencies from a few cycles up to 3000 cycles were obtained in this manner. Since the three-electrode tube has come into general use, audio oscillators[1] having iron cores have been used. In order to get any considerable range of frequency it is necessary to substitute several coils and condensers from time to time. This is troublesome, and each coil or condenser calls for a new calibration.

If two oscillators which are oscillating at radio frequency are tuned so they are near the same frequency a continuous note is heard in a telephone which is connected to one of the oscillators. This note is due to the alternating currents producing beat, caused by the difference of the frequencies of the oscillators. The frequency of this current can be made anything from near zero to frequencies above the limits of hearing. The intensity of this current is small but this can be amplified to usable values by means of a resistance amplifier. If tone intensity and purity are not items, an ordinary iron core transformer coupled amplifier can be used.

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[1] Ramsey, R. R. Experimental Radio (Revised), p. 59.

The object of this paper is to describe a simple oscillator which can be set up by any one in a short time and which will answer for most purposes.

If one takes an ordinary .001 microfarad variable condenser and a coil which will give a maximum wave length of about 12000 meters and plots the frequency curve for the combination, one will get a curve which has great curvature for small capacity and becomes almost a straight line for the higher values of the capacity. One can choose two points on the curve such that the difference of the capacity is .00025 microfarads and the difference in the frequency is 5000 cycles. This curve between the two points is not far from a straight line. If one has two such oscillators and sets them so as to oscillate at the particular frequency corresponding to the first point, place a .00025 condenser set at zero in parallel with one of the condensers, and then changes the capacity of the small condenser, he can get any audio frequency he wishes between zero cycles and 5000 cycles per second. The small condenser should be made of semi-circular plates so that the capacity is proportional to the dial setting. With a 0 to 100 division dial each division on the dial corresponds to 50 cycles.

The curves in figure 1 give the calibration of an oscillator which consisted of a 400 turn honey-comb coil and an .001 microfarad condenser variable air condenser with a 0 to 100 dial. Since the capacity was found to be proportional to the dial readings the abscissas are plotted as dial readings instead of in terms of capacity. The straight line was obtained by plotting the square of the wave length, λ^2, against the dial readings. The data for this curve were obtained by comparing the oscillator to an oscillating wave meter whose maximum range was 5000 meters. The points in circles, ⊙ are the points obtained by comparing the fundamental for no beat note. The points in the squares, ⊡ obtained from the first overtone, ratio one to two, and the points in triangles, ◬ were obtained from the second overtone, ratio one to three. Since wave length squared is proportional to capacity theoretically we should get a straight line. By drawing a straight line through the mean position of the points we get an average of all the points. By reading wave length squared off the straight line we can calculate the value of the wave length at various points and the curved line λ, is obtained. This is the curve which starts near 3000 meters and extends to near 13000 meters at the reading of 100 on the dial. By dividing the velocity of light, 3×10^8 meters, by the wave length we have the frequency. Frequency and dial settings are plotted in the curve which starts near the top for zero dial reading and curves downward to about 23 kilocycles at 100 on the dial. The lower end of the curve flattens out and a small portion of it is not far from a straight line. It will be noted that the frequency which corresponds to 57 on the dial differs from the frequency which corresponds to 82 on the dial by exactly five kilocycles or 5000 vibrations. The capacity change between the two points corresponds to 25 divisions on the dial, or one-fourth of the total of the .001 condenser, or .00025 microfarads. In figure 1 a straight line has been drawn just above the curve connecting these points, in order to show how near the curve approaches a straight line.

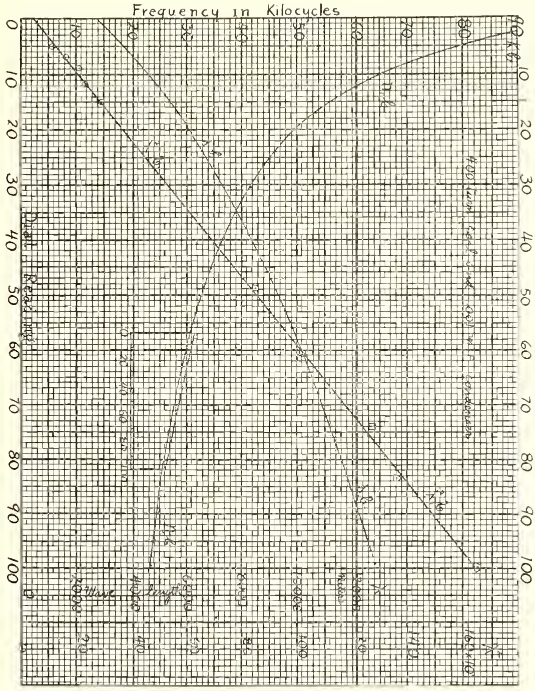

Fig. 1. Calibration curves of the audio oscillator. The curve showing the frequency is approximately a straight line through a change of frequency of 5000 vibrations.

If the oscillator condenser is clamped so as to remain fixed at the value corresponding to 57, and a .00025 condenser is placed in parallel and set at zero capacity, and a second oscillator is set so that the beat frequency between the two oscillators is zero, then as the small condenser is changed the beat frequency will change.

If the small condenser has a dial reading to 100 divisions, 0 division corresponds to 0 frequency, 100 divisions to a frequency of 5000 cycles; 50 divisions on the dial will give approximately a frequency of 2500 cycles.

If more accuracy is needed, the frequency should be read off of the curve between the two points instead of off of the straight line. Using the straight line the average error is about five per cent.

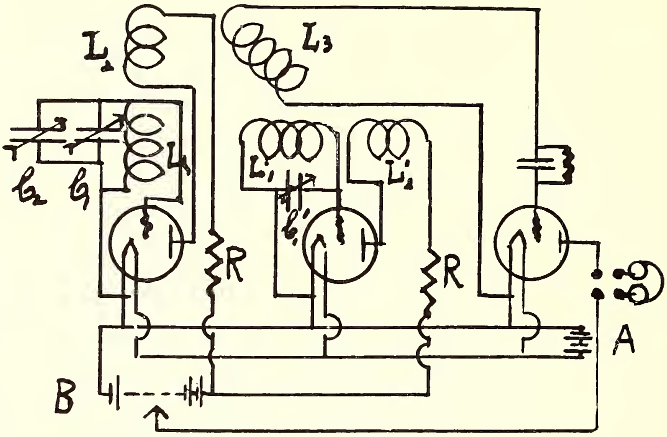

Fig. 2. Diagram of the connections of the audio oscillator.

The diagram of the connections is shown in figure 2. Each oscillator consists of a honey-comb coil of 400 turns, $L_1 L_1^1$ with a tickler coil of 150 turns, $L_2 L_2^1$, in the plate circuit, and a .001 variable air condenser, C_1 and C_1^1. Resistances of 20,000 ohms are inserted, one each in the plate circuit of the tubes which were 201A amplifier tubes. The B battery was 45 volts. The purpose of the resistances is to suppress harmonics in the oscillator.

The coils of the two oscillators are placed so that one set of coils is perpendicular to the other set of coils. The pick-up coil, L_3, is a 1200 turn honey-comb coil connected to a detector tube. This coil is placed so as to make angles of about 45° with each oscillator. C_2 is the .00025 microfarad condenser placed in parallel with C_1. The intensity of the current as it comes from the detector is great enough for most work where a head set is used. One stage of amplification makes the intensity about right. Two stages make the intensity very loud. The intensity probably changes with the frequency. Measurements have been made using an ordinary four-stage iron core transformer amplifier. The output of this amplifier changes a great amount with frequency changes, the maximum current output being for 500 cycles. The relative intensity of the sound from the loud speaker changes much more than the relative intensity of the sound from a head set in the plate circuit of the detector tube. The indications are that if a good resistance amplifier was used the intensity variation with frequency would not be so great.

In many cases the change with frequency is immaterial, since null methods are used. This is true in measuring the amplification of an audio transformer.[2]

The oscillator is very simple in construction and is one that can be made in most laboratories, either permanently or "scrambled" together for the occasion. If a greater range of frequencies is wanted, smaller coils can be used. If the oscillator is constructed with coils which give a maximum wave length of 6000 meters, two points can be found such that a difference of .00025 microfarads capacity corresponds to a frequency change of 10,000 cycles per second. With such a set more care must be used to avoid overtones than is necessary in the oscillator described.

If an oscillator is made with the above coils and enough capacity in parallel with the .001 microfarad variable condenser to make the wave length about ten or twelve thousand meters, selecting two points such that the frequency difference is 5000 cycles and the capacity difference is .00025 m. f., then the curve so joining the two points will be more nearly a straight line.

It may be well to call particular attention to the fact that all condensers used in this oscillator are of the semi-circular plate condenser type. The modern so-called straight line frequency condensers will not give anything like a straight line.

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[2] Ramsey, Ind. Acad. Proc., 213, 34, 1924.

CALIBRATION OF AMMETERS AT RADIO FREQUENCIES.

HERBERT HAZEL, INDIANA UNIVERSITY.

The phenomenal development within the last few years of appliances utilizing electric current at radio frequencies has rendered the problem of measurement of current and resistance at these high frequencies of great importance. The progress in methods of radio communication especially has given marked impetus to such a study. The measurement of resistance and of current can not easily be separated and since the two are mutually bound together, the calibration of an ammeter for particular frequencies is an important item.

While marked achievement has characterized the field of radio investigation in general, the method of calibrating ammeters for radio work has remained rather crude and inaccurate. The aim of the investigation which this paper describes has been to accurately calibrate ammeters over a wide range of radio frequencies, and, if possible, to devise a new scheme for such calibration. In the following discussion and data calibration curves have been worked out for commercial ammeters at frequencies of 1,000,000 (300 meters wave length), 10,000,000 (30 meters) and 60,000,000 (5 meters) cycles. More important than this is the application of a device involving basic principles of electron emission to the calibration of ammeters, and the successful checking of data worked out by the new method with the calibration curves obtained by the old method.

THEORETICAL CONSIDERATIONS.

Skin Effect. The ohmic resistance of a given conductor is a minimum for uniform cross-sectional distribution of current. In the case of alternating currents, particularly those of high frequency, not only is the impedance in general greater than the ohmic resistance, but the ohmic resistance itself is greater than in the case of direct currents. This is due to the non-uniform distribution of current over the cross-section, or the "skin effect". We may regard the situation in two ways:

(1) The inequality of current distribution may be accounted for on the basis of differences in inductance over the cross-section of a conductor. The counter electromotive force arising from self inductance is greater at the axis or central portions of a wire than at the outer portions. The value of the current will, on this account, reach a maximum in the outer portions before the maximum is reached near the axis. Now if the direction of current be reversed rapidly, the current may not have the time between reversals to reach a maximum in the

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central portions of the conductor. As a result the current density is greater near the surface.

(2) On the basis of the ether strain theory we may consider the current in a conductor established not by a process analogous to the push of a piston in a water pipe, but by an absorption of energy all along its surface from the surrounding dielectric. If the current be reversed in direction at a high frequency, energy may not have time to "soak in" to a very great depth.

Maxwell, Heaviside, and Lord Rayleigh have developed the principles of behavior of variable currents. The following factors must be considered, according to their development, in determining the nature of high frequency currents in a circuit:[1]

(1) Resistance of the circuit.
(2) Inductance of the circuit (considering the geometric form, the material and the nature of the surrounding insulator).
(3) Capacity of the circuit (considering geometric form and the dielectric constant of the medium).
(4) Dielectric conductance.
(5) Energy dissipation due to causes other than conductance (such as dielectric hysteresis).

Lord Rayleigh has shown[2] that if R is the true ohmic resistance (for steady currents) of a cylindrical straight wire of length l and magnetic permeability μ, that the resistance is increased to R′ for a simple harmonic alternating current of frequency η, where R′ is given by:

$$R' = R\left\{1 + \frac{1}{12}\,\frac{p^2\,l^2\,\mu^2}{R^2} - \frac{1}{180}\,\frac{p^4\,l^4\,\mu^4}{R^4} + \ldots\ldots\right\}.$$

This formula shows that the effective resistance is increased as the frequency increases from zero to infinity. If the frequency is very low, the chief opposition to the current is ohmic resistance and the distribution of current over the cross-section will be uniform so as to make the opposition a minimum. If the frequency is very large, the chief opposition to current is inductance rather than ohmic resistance, and hence the distribution of current over the cross-section will be such as to make the inductance a minimum. This, of course, results in concentration of the current in outer layers of the conductor.

Computation of Resistance at Radio Frequencies. Lord Rayleigh's formula for the resistance of a straight cylindrical wire of non-magnetic material has been transformed by Fleming[3] into the expression:

$$R' = R\left\{1 + \frac{K^2}{48} - \frac{K^4}{2880} + \frac{K^6}{58647}\right\} \text{ where } K = \frac{\eta\pi^2\,d^2}{\rho}$$

which is applicable if K is less than one. (η is frequency, d is diameter in centimeters and ρ is the direct current resistivity in C. G. S. units). If η and d are such as to make K greater than one, and especially if it becomes as much as five or six, Lord Rayleigh's formula[4] has to be modified. A. Russell's modification is:

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[1] J. A. Fleming: "The Principles of Electric Wave Telegraphy."

[2] "On Self Induction and Resistance of Straight Conductors" (Phil. Magazine, May 1886, p. 382).

[3] J. A. Fleming: "Elementary Manual of Radiotelegraphy and Telephony" and "The Wireless Telegraphist's Pocket Book."

$$R' = R\left\{\frac{\sqrt{K}}{2} + \frac{1}{4} + \frac{3}{32\sqrt{K}} - \frac{1}{16k\sqrt{K}}\right\}$$

which may generally be abbreviated into simply $R' = R\left\{\frac{\sqrt{K}}{2} + \frac{1}{4}\right\}$

From the above formulae one can compute the maximum diameter a wire could have in order that its high frequency and direct current resistance may be practically the same for any given frequency. Setting R′ equal to R in Russell's formula,

$$\frac{\sqrt{K}}{2} + \frac{1}{4} = 1, \text{ whence} \sqrt{k} = 1.5. \quad \text{That is } \sqrt{\frac{\eta\, \pi^2\, d^2}{\rho}} = 1.5.$$

If we solve the last equation above for d, we have:

$$d = .4774\sqrt{\frac{\rho}{\eta}}.$$

In Circular 74 of the Bureau of Standards the maximum diameters of wires which have a ratio of $\frac{R'}{R} = 1$ (to within one per cent) have been worked out for certain frequencies and materials. Some of these values, and extensions[5] computed from them are given below.

Material	Frequency	Diameter (cm)
Copper	1,000,000	.0112
	10,000,000	.00354
Platinum	1,000,000	.0354
	10,000,000	.0112
Manganim	1,000,000	.0564
	10,000,000	.0178
German Silver	1,000,000	.0614
	10,000,000	.0195
Tungsten	1,000,000	.026
	10,000,000	.0082

---

[4] Wein and Sommerfeld have deduced an expression for the ratio of high frequency resistance, R″, of a spiral of one layer of circularly cross-sectioned wire to R, the direct current resistance as: $\frac{R''}{R} = 2\sqrt{\pi}\, \frac{1}{2}\sqrt{K}.$

E. H. Barton (Proc. Phy. Soc. London, 1889 Vol. 16) has built up a series for the resistance in the case of damped oscillations.

[5] Diameters at η equals 10,000,000 are found by dividing the value at η equals 1,000,000 by $\sqrt{10}$. The value for tungsten is found by multiplying the value for platinum by:

$$\sqrt{\frac{\rho \text{ for tungsten}}{\rho \text{ for platinum}}}$$

Measurement of Current at Radio Frequency. It is pointed out in Circular 74 of the Bureau of Standards that the measurement of current is a cardinal operation in high frequency work (even to a much greater degree than at low frequency) since it is involved in measurement of resistance as well as in most of the measurements of other quantities. An ammeter for use at radio frequencies must, first of all, meet the requirement of simplicity. A large inductance or a large capacity would tend to make the current flow through the dielectric as well as through the conductor, in an amount varying with the frequency. In the case of a hot wire ammeter the deflection of the instrument depends upon the heating effect, which, in turn is proportional to $I^2 R$. Consequently if a deflection is always to correspond to the same current, it is necessary that R should not change with frequency. The permissible diameter of the wire at any frequency is then limited as indicated in the discussion above.

It is obvious that shunts can not be safely used in the construction of ammeters for use at radio frequencies, for the mutual inductance between the parallel branches will change the distribution of currents so that the effective resistance in the circuit will depend upon the frequency. This may be true even though the separate components in the shunted arrangement be made so small that each one's resistance, if used individually, is constant over the range of frequencies used. Indeed the writer has found that the ordinary law of shunt circuits does not hold at radio frequencies, but that it is possible to place two wires in parallel with the result that the effective resistance of the combination is greater than the resistance of one of them. One is confronted, in part, by the following array of very troublesome sources of error in radio frequency ammeters:

(1) There is erratic shifting of the zero reading.

(2) Electro-static coupling and charges on the dial and case of the instrument introduce errors.

(3) Within the range of radio frequencies commonly used there occur changes in current distribution with consequent changes of resistance.

(4) Leakage from the main circuit through the indicating device on the ammeter, and through the distributed capacity of the case, etc., may cause an error which is more or less problematic. Leakage in such instruments as the self-heated thermoelement type should be considerable, according to theory, and should cause an error in a direction opposite to that caused by increase of ohmic resistance.[6]

Perhaps the most annoying source of error, and one which it seems impossible to eliminate in the ordinary hot wire instrument is the zero shifting. In Circular 74 of the Bureau of Standards (p. 149) a rather elaborate method is given for the correction of a zero error. Such a procedure requires considerable time and is scarcely practicable for commercial work. It is certain, however, (see table I, p. 153) that unless special precautions are taken, the zero shift will cause well constructed ammeters to vary among themselves and each one to vary with different trials by as much as ten per cent at one frequency.

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[6] Some experimental evidence in regard to the effect of capacity across the instrument terminals indicates that parallel resonance at particular frequencies may be the most important factor.

CALIBRATION OF AMMETERS.

Calorimeter Method. The calorimeter arrangement employed by Fleming in measuring high frequency resistance can be used also in the calibration of ammeters. The apparatus involves only fundamental relationships, but is slow in action, and not extremely accurate, even at the best. The device as used in the investigation described in this paper consisted of two large glass tubes (4.3 cm. in diameter and 23 cm. long) sealed air tight with rubber stoppers at the ends and connected with a water manometer as shown in figure 1. It was found from experiment that the volume of each tube should be very large in comparison with the volume of the manometer tube. Two resistance wires, R_1, and R_2 as nearly alike as possible are soldered at the ends to short pieces of heavy copper wire, and one resistance is placed in each tube with the heavy copper wires protruding at the ends for making electrical connection.

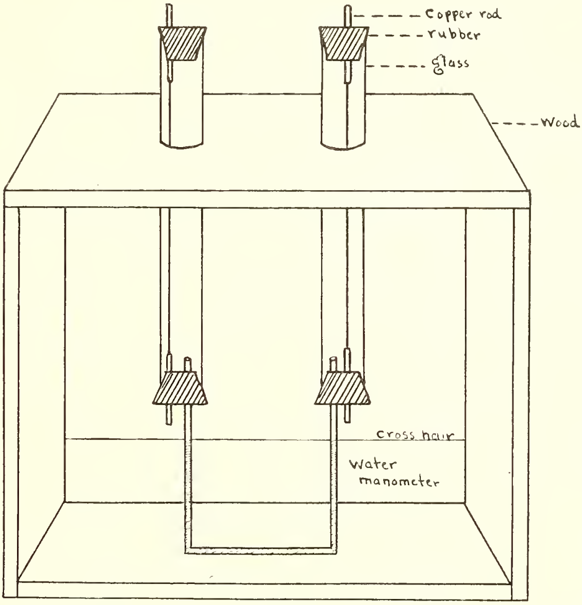

Fig. 1. Device used in the investigation for the calibration of ammeters.

If an unknown high frequency current, i, be sent through R_2,[7] and the manometer balanced by direct current I_1, sent through R_1, then

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[7] The two resistances in this particular apparatus were platium wires 16 cm long and of .00762 cm diameter. As may be seen from the table on page 147, this wire is small enough that its resistance at a frequency of 10,000,000 is within one per cent of its resistance for direct current.

(1) $I_1^2 R_1 = k\iota^2 R_2$, where K is some constant depending on the relative volumes and heat capacities of the two sides of the apparatus. Similarly if ι without change in magnitude be sent through R_1, and the balance restored with direct current I_2, through R_2,

(2) $\iota^2 R_1 = kI_2^2 R_2$ (if the wires have the same resistance for high frequency and direct current). Dividing equation (1) by equation (2) and solving for ι, $\iota = \sqrt{I_1 I_2}$,

The apparatus was carefully tested for leaks both before and after measurements were made. In addition two tests were made to determine the accuracy of the device by sending known direct currents through both resistance wires. With a current of .3 ampere, a change of current of .05 ampere changed the difference of levels in the manometer by 2 centimeters. By means of the cross hair one could easily read the levels to less than .5 millimeter, hence a change of current of .001 ampere could easily be detected. Of course the radio frequency current measured was, in general, not constant by any means, so the actual accuracy attained in practice was considerably less than .001 ampere at .3 ampere. The test with known direct currents indicated an average percentage of error of 1.25 over the scale range of .2 ampere to .4 ampere. This represents the inevitable percentage of error involved in the calibration apparatus. Any errors in an ammeter reading larger than one or two per cent, however, must be attributed to defects in the instrument under test at the particular frequency used.

The oscillator used for production of current at frequencies as high as 10,000,000 was of the Hartley shunt type shown in part A of figure 2. The heat apparatus and ammeters to be calibrated were connected in the tuned coupled circuit shown in part B figure 2.

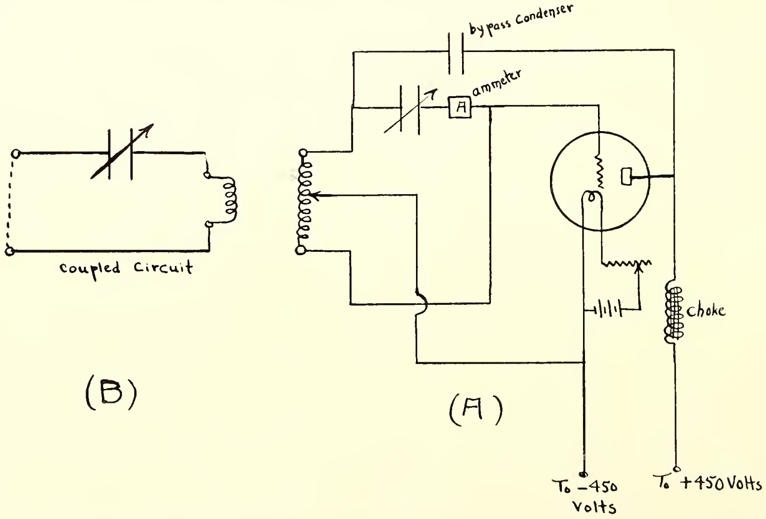

Fig. 2. The oscillator used for production of current is shown in A. The heat apparatus and ammeters to be calibrated were connected in the tuned circuit shown in B.

Calibration curves have been worked out at 1,000,000 and at 10,000,000 cycles for each of the following radio frequency ammeters:

Jewell (1 ampere, metal case) pattern 64; Jewell (.5 ampere) pattern 64; Weston (1.5 ampere) model 425; and Westinghouse (1 ampere) type PX-2.

Curves have also been worked out for Weston (100 milliamperes) model 425 at frequencies of 10,000,000 and 60,000,000. Some comparisons of the behavior of ammeters with metal and with bakelite cases (two Jewells model 425 and others listed above) have also been made. The instruments could be read accurately as follows: Jewell (1 ampere) at .3 ampere to within .01 ampere. Jewell (.5 ampere) at .3 ampere to within .005 ampere, Westinghouse (1 ampere) at .3 ampere to within .01 ampere and Weston (100 milliamperes) at 50 milliamperes to within 1 milliampere.

DATA AND RESULTS.

In order to determine how one radio frequency ammeter varied with successive readings at a particular frequency, and how different ammeters varied among themselves with successive readings at the same frequency, three ammeters (Weston, Jewell (1 amp) and Westinghouse) were connected in series and three sets of readings were made. After varying the current as indicated by the Weston instrument through the range of three-tenths ampere to one ampere and recording the corresponding readings of the other two instruments, the operation was repeated twice keeping the Weston readings constant and recording again corresponding readings (trials 2 and 3) of the other two ammeters. It may be seen from the data in table I and the curves in figure 3 that both the Jewell and Westinghouse ammeters varied individually and also with each other by as much as ten per cent. This in no way indicates a superiority in the Weston instrument, for on keeping either the Jewell or Westinghouse reading constant, the Weston ammeter was also found to vary individually with successive trials. It should be noted that the calibration curves are somewhat convergent toward the upper end of the scale.

TABLE I. Comparison of Ammeters in Series at 1,000,000 Cycles

Weston	Jewell (1 amp.)			Westinghouse		
	Trial 1	Trial 2	Trial 3	Trial 1	Trial 2	Trial 3
.3	.295	.27	.26	.33	.3	.3
.4	.39	.365	.375	.44	.41	.415
.5	.49	.465	.48	.54	.51	.52
.6	.6	.585	.58	.65	.635	.63
.7	.69	.68	.68	.74	.725	.725
.8	.78	.78	.78	.82	.82	.82
.9	.875	.875	....	.91	.91	....
1.0	.985	.985	....	1.0	1.0	....

The next few pages summarize data taken with several commercial ammeters by means of the heat method of calibration described on page 149. Several sets of readings were taken at each frequency used in the research work for purposes of checking on each ammeter, but only representative curves are described in this paper. In general the different ammeters behaved similarly so that the data on one ammeter

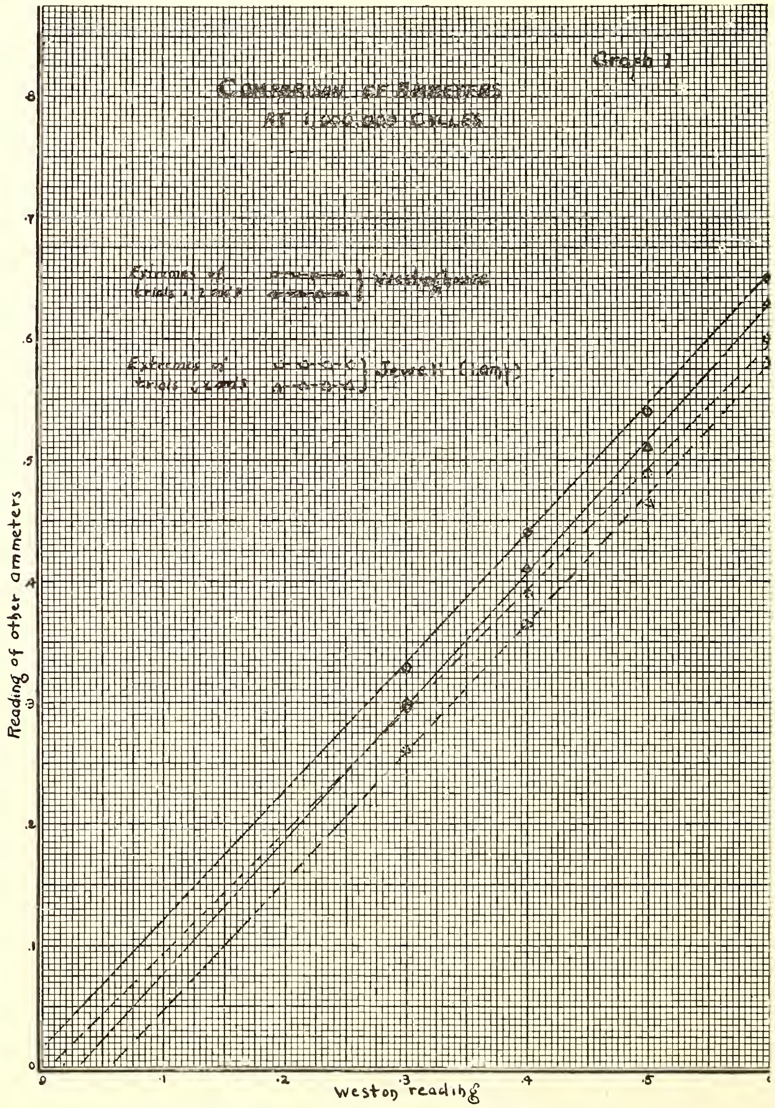

Fig. 3. Comparison of ammeters at 1,000,000 cycles.

approximately characterized the action of the others. It might be mentioned that the Jewell (.5 ampere ammeter) approached more closely to the line of zero error at all frequencies than any other instrument used. The behavior of the Westinghouse ammeter is indicated in the data of tables II and III and in figure 4.

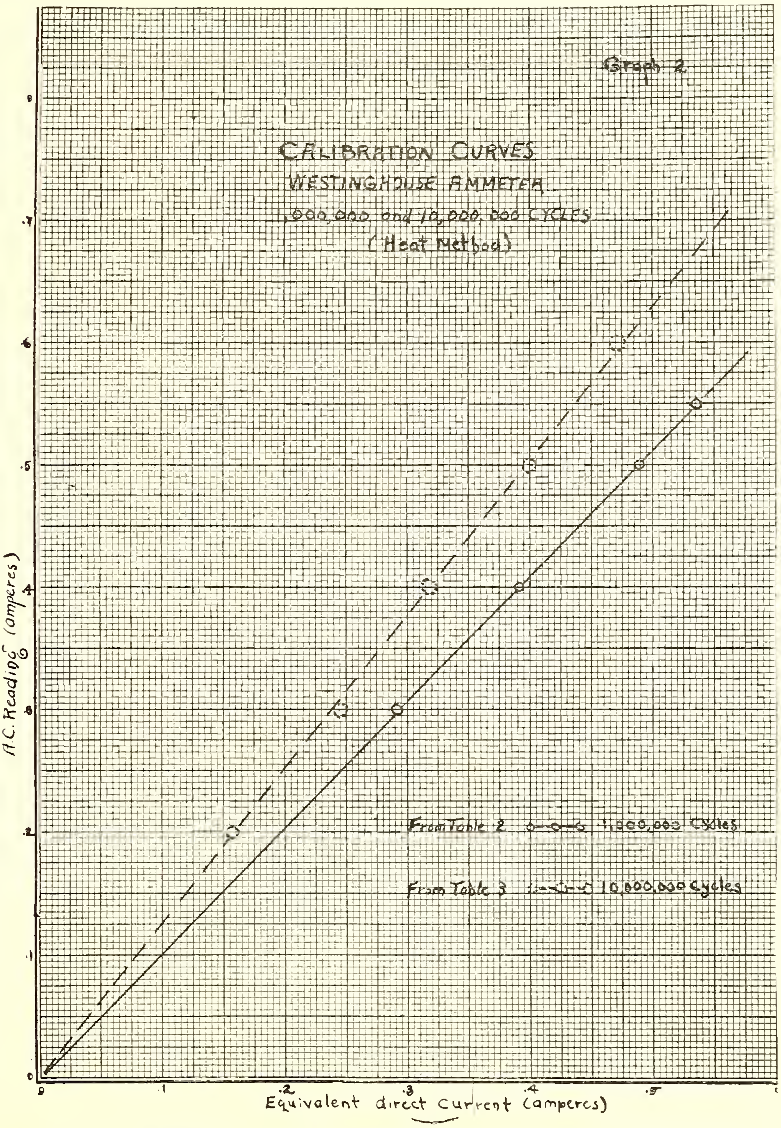

Fig. 4. Calibration curve for the Westinghouse ammeter (type px—2).

It would be expected that if the skin effect predominated in an ammeter, its reading should be too high. If one should plot its reading along the y axis and the equivalent direct current along the x axis, the resulting calibration curve would then lie above the line of zero error. Figure 4 indicates just this situation in the Westinghouse instrument. The calibration curve lies above the line of zero error and is steeper than the line of zero error. With this particular ammeter the skin effect is pronounced at a frequency of 10,000,000 cycles per second. For instance when the reading was six-tenths ampere at this frequency the actual current through the instrument was only .472 ampere which indicates an error of 27 per cent. If the skin effect is neutralized by factors which tend to make an ammeter reading too low on high frequency current, such as leakage through capacity shunts in the case and movement, then the calibration curve may fall below the line of zero error. With an increase of frequency the slope of the calibration curves of most of the ammeters was increased. Even though the reading of an instrument was low at 10,000,000 cycles, it was in general higher than at a frequency of 1,000,000 cycles. The results for all ammeters used are summarized in table IV.

TABLES II and III. Calibration of Westinghouse Ammeter

1,000,000 CYCLES (Heat Method) 10,000,000 CYCLES

Experimental			Computed	Experimental			Computed
A. C.	D.C. I_1	D.C.I_2	A. C.	A. C.	D.C. I_1	D.C. I_1	A. C^2
.3	.255	.34	.294	.2	.227	.11	.158
.4	.355	.435	.393	.3	.287	.21	.245
.5	.455	.53	.49	.4	.36	.28	.317
.55	.5	.57	.534	.5	.423	.38	.401
				.6	.485	.46	.472

TABLE IV. Summary of Ammeter Calibration

Instrument	Reading at 1,000,000	Reading at 10,000,000	Reading at 60,000,000
Westinghouse	Slightly high	Very high	
Jewell (1 amp)	Considerably low	Slightly low	
Jewell (.5 amp.)	No appreciable error	No appreciable error	
Weston (1.5 amp.)	Slightly low	Slightly low	
Weston (Milliammeter)		High on lower end of scale Low on upper end of scale	Considerably low

II. A NEW METHOD FOR CALIBRATING AMMETERS AT RADIO FREQUENCIES.

The calorimeter method is crude and inaccurate at the best. The following discussion concerns a new method, which, over a limited range is much more sensitive and at the same time much better adapted to rapid work. The device involves only the fundamental physics of electron emission and the action of a thermionic vacuum tube. In fact, an ammeter may be dispensed with and the calibration instruments described below used directly to measure radio frequency current.

THEORETICAL CONSIDERATIONS.

If direct current is sent through the filament of a vacuum tube, on closing the circuit the temperature of the filament begins to rise at a rate controlled by the net gain of calories per second and the material and dimensions of the filament. That is, the rate of increase of temperature is proportional to calories received minus calories lost, the quantity divided by the heat capacity of the filament. Now the number of calories received per second is proportional to I^2R, and since R changes with temperature the rate of heat production varies. At first, when the filament is cold, R is small and so the heat production will be relatively large. Also the rate of loss of calories will be small because the temperature of the filament is low. These factors combine to produce a large initial rate of temperature change. As the temperature increases R increases and I decreases, so that I^2R decreases. At the same time the rate of loss of calories will increase with rise of temperature with the consequence that rate of increase of temperature decreases. Now radiation is the chief source of loss of heat in a vacuum tube, and the rate of radiation, being proportional to a high power of the temperature, increases very rapidly. At some instant the calories lost will equal the calories received and the temperature will cease to change. If we should plot temperature against time we should have such a curve as shown in figure 5.

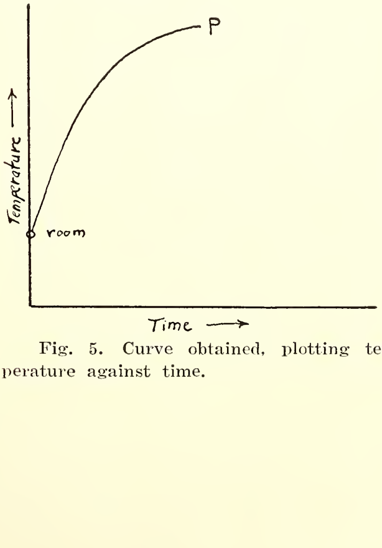

Fig. 5. Curve obtained, plotting temperature against time.

The exact curve would, of course, depend upon the current, heat capacity of the filament, etc. If when the temperature has reached the point P, the current is stopped, cooling will follow a symmetrical curve, (dotted) as shown in figure 6 because the same factors control the rate of decrease of temperature as well as the rate of increase. If we should intermittently open and close the circuit through the filament, the temperature would increase on the solid curve, and decrease on the dotted curve.

Between room temperature and A, the intersection of the curves, the rate of increase is greater than the rate decrease, but from A upward the rate of decrease is greater than the rate of increase. Hence A will be the mean value about which the temperature will vary for intermittent current. If the period of interruption of the filament current is small compared to the time required to reach the steady temperature when the uninterrupted current is turned on, the value of the temperature will not vary much on either side of A.

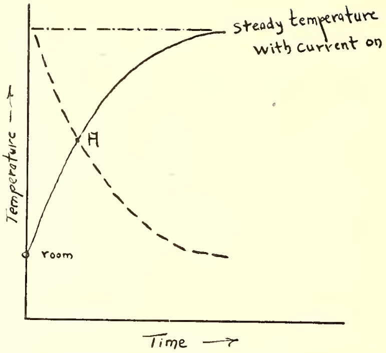

Fig. 6. Cooling follows a symmetrical curve (dotted) when current is stopped after the temperature has reached the point P.

Now if a simple harmonic alternating current be used instead of an intermittent direct current, the curves would be modified somewhat. Starting with a small current the temperature would rise more slowly than in the case of direct current. The curve would appear as in figure 7, which resembles a typical filament temperature-plate current characteristic curve for a vacuum tube. Again the temperature will have a mean value at A, the intersection of the curves, and if the period of the high frequency current is very short compared with the time required to raise the temperature from room value to its maximum value, B, then the value of the temperature will not vary much from A. From these considerations it seems safe to assume that with frequencies of several thousands the temperature of a vacuum tube filament due to an alternating current will be the same as the temperature of the filament produced by an equivalent direct current. With low frequencies the validity of the assumption would hold only for the mean value of the temperature.

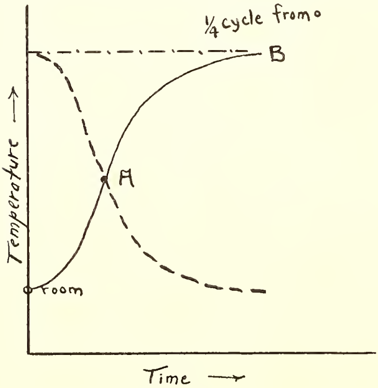

Fig. 7. Modification of curves if a simple harmonic alternating current is used instead of an intermittent direct current.

If the filament of a two electrode themionic vacuum tube be small enough that its resistance for direct current or 60 cycle alternating current is equal to its resistance for current at a given radio frequency, the latter current should produce the same average filament temperature that is produced by the equivalent direct current. As has been pointed out, the temperature will not even fluctuate about the mean value to any appreciable extent if the frequency of the alternating current is very high. Now the rate of electron emission of a hot filament

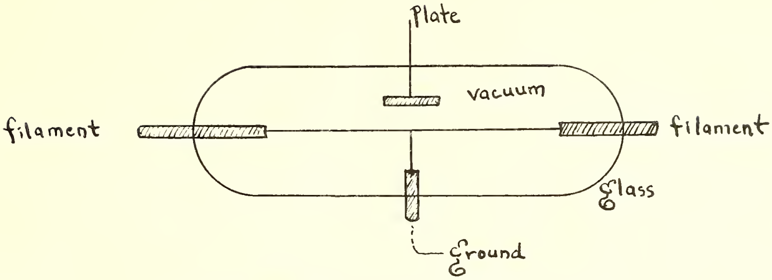

Fig. 8. Construction of tube used in experiments.

is a function of the temperature. Hence a radio frequency current through the filament which produces a given plate current is equal to the direct current which, if sent through the filament, will produce the same plate current, provided the potential gradient from filament to plate is the same in the two cases. In order to meet this condition the filament may be made non-inductive, the filament plate capacity may be made practically zero, and 60 cycle alternating current substituted for direct current. The reason for using 60 cycle current instead of direct current, is that with one leg of the filament grounded in the case of direct current it is either the positive or negative leg always, a situation which would not be duplicated with alternating current. A tube constructed as indicated in figure 8 would meet the requirements. The mid point of the filament may, if desired, be grounded as shown by the dotted line.

Since it is only necessary to get a measurable plate current, the plate may be made very small.

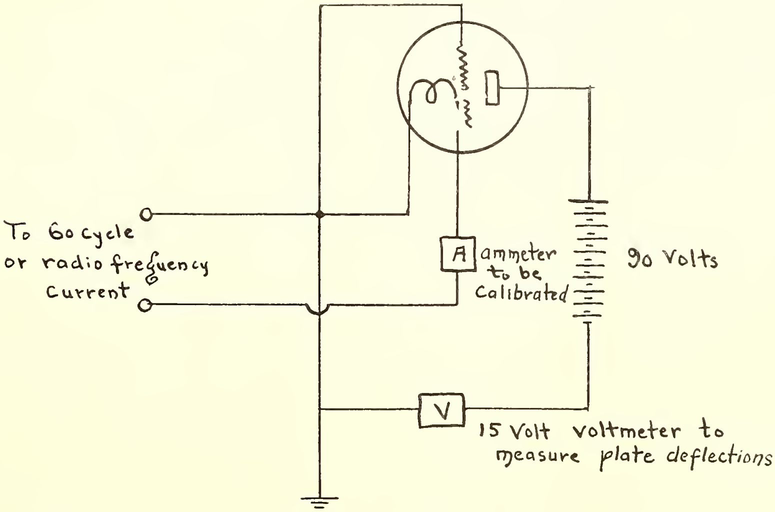
To 60 cycle or radio frequency current
A
ammeter to be Calibrated
90 Volts
V
15 Volt voltmeter to measure plate deflections

Fig. 9. Arrangement of apparatus and connections used in experiments.

A commercial amplifying tube for radio receiving sets does, of course, not quite meet the above requirements in that the plate is large, the filament is slightly inductive, and the presence of the grid offers possibilities for such undesirable occurrences as eddy currents and irregular modification of the potential gradient between the filament and plate.

DATA AND RESULTS.

The following measurements show how nearly the predicted results may be obtained even with an ordinary radio receiving tube. The arrangement of apparatus and connections used are shown in figure 9.

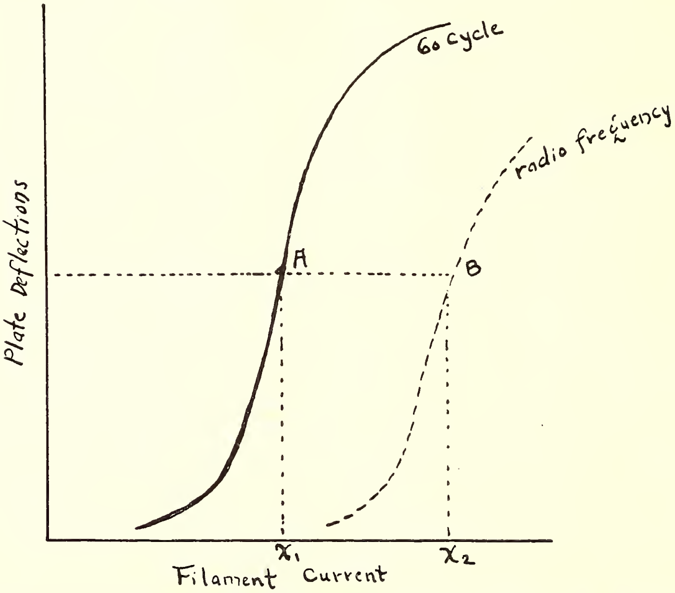

Fig. 10. By comparing the two characteristic curves obtained, the true value of the radio frequency current through the filament is determined.

In order to calibrate an ammeter by the vacuum tube method it is necessary to obtain the filament current-plate current characteristic curve of the vacuum tube used—by plotting filament current at 60 cycles against the plate current. The plate current, or deflections proportional to the plate current may be obtained by placing a voltmeter or a micro or milliammeter in the plate circuit of the tube as shown in figure 9. The filament current at 60 cycles must be accurately measured by some instrument which is calibrated for use at this low frequency. Usually the radio frequency ammeter to be calibrated may be used for this purpose. The characteristic curve should then be again obtained, this time substituting current of the desired high frequency through the filament instead of 60 cycle current. If the current through the filament and the plate deflections have been accurately measured in both cases, the same characteristic curve should result. If, however, the tube curves (one obtained with 60 cycle current through the filament and the other with radio frequency current through the filament) do not coincide, some error has been made in measurement.

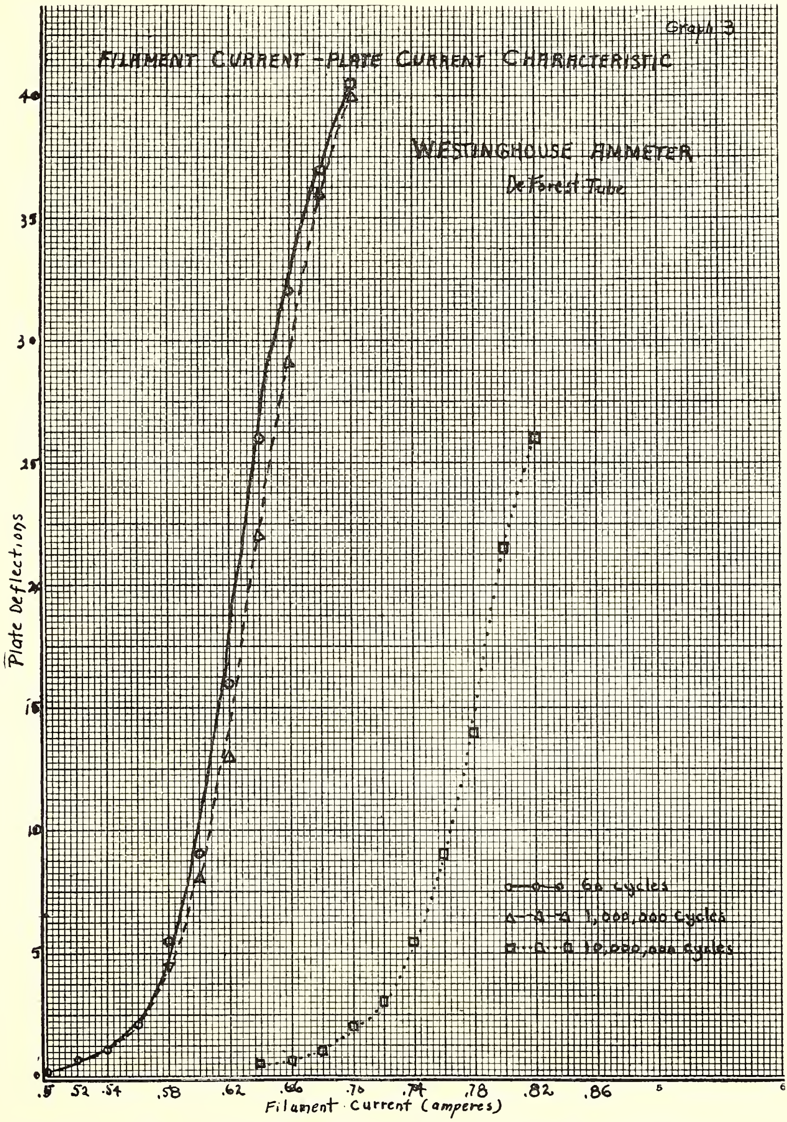

Fig. 11. Vacuum tube characteristic curve for the Westinghouse ammeter.

Now one can easily measure 60 cycle current and direct current in the plate circuit with accuracy, so any discrepancy between the curves may be traced to errors in measuring the radio frequency current through the filament. If the precautions already mentioned concerning the construction of the tube and the arrangement of the circuit in which it is used are taken, one can find the true value of the radio frequency current through the filament by comparing the two characteristic curves. For example, let the solid line in figure 10 be the curve for accurately measured 60 cycle current through the filament, and let the dotted line be the curve obtained with radio frequency current through the filament. From the 60 cycle curve, x_1, is the true value of

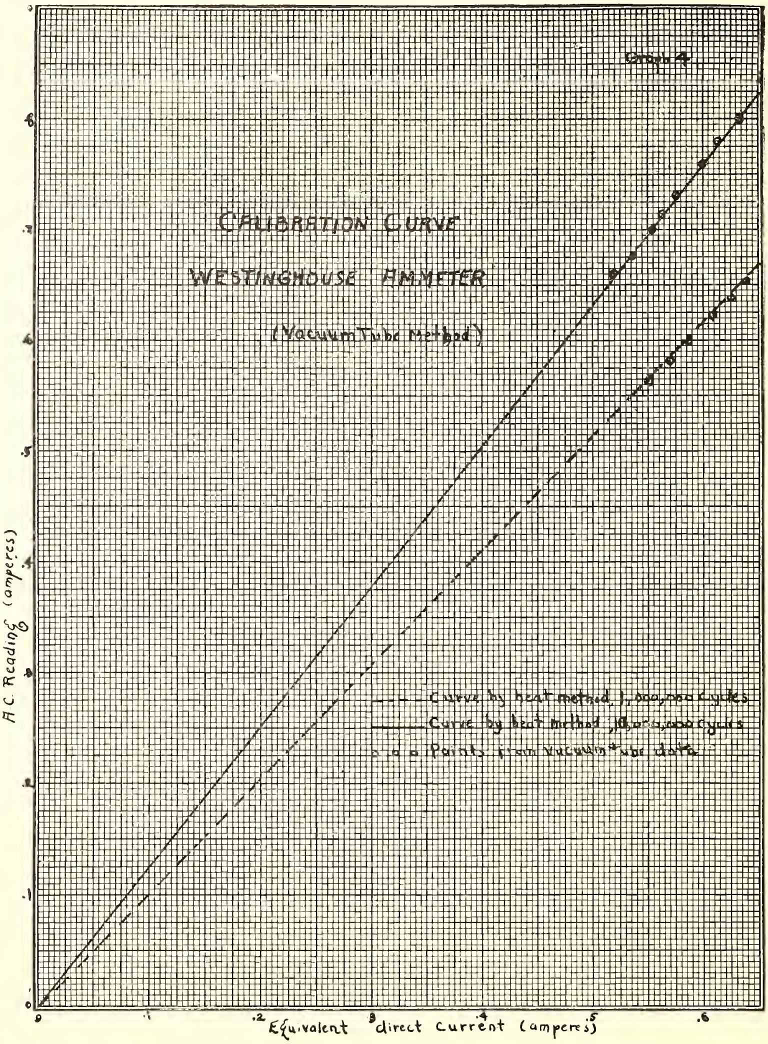

Fig. 12. Comparison of calibration curves as obtained by the heat method at 1,000,000 and 10,000,000 cycles, respectively.

the filament current which produced the plate deflection at A. Then tracing across horizontally to the point B on the radio frequency curve at which the same plate deflection occurred, one sees that x_2 was the reading of the ammeter for the filament current which produced the plate deflection, B. That is x_2 is the reading of the instrument which corresponds to the true value of current x_1. Hence the calibration curve can easily be plotted from this data. Table V and figures 11 and 12 show the curves for the Westinghouse ammeter. In figure 12 the calibration curves already found by the heat method (fig. 4) are plotted and values from the characteristic curves of figure 11 are shown in circles. It will be seen that the curve obtained by the vacuum tube method practically coincides with the one obtained by the heat method.

TABLE V. Filament Current–Plate Current Characteristic
De Forest Tube

WESTINGHOUSE AMMETER

60 Cycles (May 11)		1,000,000 Cycles (May 20)		10,000,000 Cycles (May 11)	
Filament Current (Amperes)	Plate Deflections	Filament Current (Amperes)	Plate Deflections	Filament Current (Amperes)	Plate Deflections
.5	.2	.52	.2	.64	.5
.52	.7	.54	1.0	.66	.6
.54	1.0	.56	2.0	.68	1.0
.56	2.2	.58	4.0	.70	2.0
.58	5.5	.6	8.0	.72	3.0
.60	9.0	.62	13.0	.74	5.5
.62	16.0	.64	22.0	.76	9.0
.64	26.0	.66	29.0	.78	14.0
.66	32.0	.68	36.0	.80	21.5
.68	37.0	.7	40.0	.82	26.0
.70	40.5				

SUMMARY.

Some of the outstanding limitations of the ordinary radio frequency ammeter have been demonstrated. Not only is there considerable variation with frequency, but variations at any particular frequency, due chiefly to the zero shift, are not to be ignored. At extremely high frequencies the insertion of an ammeter in the circuit would so profoundly change the constants of the circuit that its use would be worthless.

The problem of measuring rather large radio frequency currents with great accuracy has not been completely solved. The distributed capacity of the commercial hot wire ammeter introduces factors of unsolved complexity.

An application of the special form of thermionic vacuum tube described in this paper offers solution to all these difficulties in a new form of radio frequency ammeter. The indications of such a device, depending on the fundamental property of electron emission of hot bodies, would be practically instantaneous in its action, and comparatively free from zero shifting. Since a given tube could, from the nature of its functions, cover only an extremely limited range of current, and since the change of plate current with a very small change of filament current can be made enormously large, the instrument would be "microscopic" in its accuracy. Tubes of tiny dimensions can be constructed with negligible inductance and capacity, offering opportunity for use in circuits of extremely high frequency, and offering possibility of combination in parallel for measuring large currents. Several tubes can be mounted in one set with a single galvanometer for recording the plate current, so that a large range of current magnitude may be taken care of. In conclusion, it seems that one may add the much needed ability to measure radio frequency current to the already long list of applications of the thermionic vacuum valve.[8]

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[8] I wish to thank Prof. A. L. Foley who placed the facilities of the physical laboratory of Indiana University at my disposal. I wish to acknowledge my indebtedness to Prof. R. R. Ramsey, who suggested this problem, for his help and guidance during the progress of the investigation. Prof. M. E. Hufford and Mr. John H. Miller, electrical engineer of the Jewell Electrical Instrument Co., also very kindly co-operated with me in the study.

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R. EARL MARTIN, Indiana University.

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[1] Omitted from volume 35 of Proceedings because of lack of space.—Editor.

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NOTES ON QUALITATIVE ANALYSIS

RALPH W. HUFFERD, DePauw University.

ZINC.

Considerable uncertainty arises in the use of either hydrogen sulphide or potassium ferrocyanide as a direct test for zinc after the removal of aluminium hydroxide. The presence or absence of chromium also seems to afford two distinct conditions when zinc is sought by the inexperienced student.

The writer avoids these difficulties by always having a colored solution prepared by adding chromate if absent, and by removing a sufficient amount of the zinc from the main solution for distinct tests under unvarying conditions.

Method.—If chromium is absent (solution colorless), after removing aluminium hydroxide, add about five drops of dichromate solution. Acidify the ammoniacal solution with acetic acid, using the color change from chromate to dichromate as an indicator. A few cubic centimeters excess can do no harm. Saturate 5 cc. water with hydrogen sulphide and add the resulting solution to the above acidified solution. Let stand for a minute or two and filter, returning the filtrate to the filter about three times. As a general rule, if zinc is present, a flocculent precipitate is easily seen and filtered off; but if it is absent, a solution of milk of sulphur, which appears quite clear but milky, results.

Wash the filter with hot water and then pass through it a hot solution of 2 cc. 6N hydrochloric acid in 10 cc. water. Pass the filtrate through again (hot) and boil to expel hydrogen sulphide. Cool, make alkaline with ammonia, acidify with acetic acid, and divide into two portions. To one part add four or five drops of ferrocyanide solution and to the other 2 cc. saturated hydrogen sulphide water. White precipitates of zinc ferrocyanide and zinc sulphide respectively are obtained if zinc is present.

CALCIUM.

The difficulty which some students experience in making precipitation tests in colored solutions has led most writers to advise a second precipitation of calcium and strontium as carbonates after removing barium as the chromate. The writer avoids this difficulty by making a very definite control test.

Method.—After removing barium and detecting strontium by the customary side test with calcium sulphate solution, add excess ammonium sulphate solution and boil down the solution to about four-fifths volume. Filter hot. Boil down the filtrate to about 15 cc. and filter through the original filter until perfectly clear. Divide into two equal portions in large test tubes and dilute with three volumes

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of hot water. To one tube add one drop of saturated calcium sulphate solution and shake to mix. To each tube add five drops of ammonium oxalate solution. Stopper the tubes and shake for about two minutes. Compare the two. A white precipitate at least as heavy as the one in the tube to which the calcium sulphate was added should form in the second if calcium is present.

AN INDESTRUCTIBLE STEAM BATH.

RALPH W. HUFFERD, DePauw University.

The lack of durability and high cost of commercial constant-level steam-baths put out by supply houses led the writer to devise one from standard plumbing supplies. This bath has been found to be very satisfactory and practically indestructible. The cost is about one-third that of those on the market.

The bath consists of a standard pipe coupling with a plug screwed in. The constant-level device is made up by screwing two ½-inch nipples 1½ inches long into a ½-inch T. Into the third opening of the T is screwed a one-hole rubber stopper carrying a piece of glass tubing. This tube is raised or lowered to regulate the level. Water is introduced by means of a second piece of tubing bent into the shape of a hook and hung into the top nipple.

To attach the leveling device, a hole is drilled into the coupling just above the plug. The hole is threaded.

The writer has baths made from both four and five-inch couplings. When needed, rings from discarded commercial baths are used.

TOXICITY OF COLLOIDAL ARSENIC TO PLANTS.

R. H. CARR, Purdue University.

Questions frequently arise relative to the limits of toxicity of different forms of arsenic, not only in cases of accidental poisoning of animals, but also from possible injury to plants when arsenic is used as a constituent of sprays.

The solubility of white arsenic (As_2O_3) in water is rather small, that of the crystalline form being given in solubility tables as about 1.7 grams per 100 cc. at 15°C., whereas that of the amorphous form is nearly double this amount at the same temperature. However, the toxicity of this most ancient poison is very difficult to estimate as it becomes greatly modified when mixed with colloidal matter with which it is usually associated in living tissues.

Colloidal Condition.—A colloid has been defined as a solid which has been changed to surfaces, or as matter which is too small to be called a suspension and too large for a solution. Thus it becomes a problem to measure accurately the effectiveness of colloidal arsenic which is so finely divided that it is only a little short of a solution.

Efficiency of Colloidal Arsenic as a Rat Poison.—The toxicity of colloidal arsenic (As_2O_3) as a rat poison has recently been studied at The Mellon Institute of Industrial Research by Hedenburg.[1] He experimented with the amount of arsenic necessary to kill rats, and the time required for death to ensue after partaking of the poison, both when it was eaten in a colloidal and in a non-colloidal form. It was found that as little as 0.5 gram of a colloidal arsenic mixture containing 30 per cent arsenic would kill a rat in about 30 minutes, whereas the same quantity of arsenic in a non-colloidal form caused death to another rat only after 24 hours.

Limits of Toxicity of Colloidal Arsenic to Plants.—In view of the fact that colloidal arsenic has been shown to be so much more effective upon animals than the non-colloidal form, an effort was made by the writer to test the toxicity of arsenic to plants when present in a colloidal form.

Plan of Experiments.—Geranium plants six to ten inches in height were chosen for the experiments because they were found to be quite sensitive to this poison and because their large leaf surface gave good contact and slightly toxic indications could be easily recognized. The arsenic (As_2O_3) used was ground sufficiently to pass a 200-mesh sieve after which samples of 0.1 gram were weighed and placed in small flasks in a ball mill to enable the arsenic to be ground intimately with

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[1] Hedenburg, O. G.—Memorandum on a new rat poison. The Practical Druggist—Sept. 1926.

"Proc. Ind. Acad. Sci., vol. 36, 1926 (1927)."

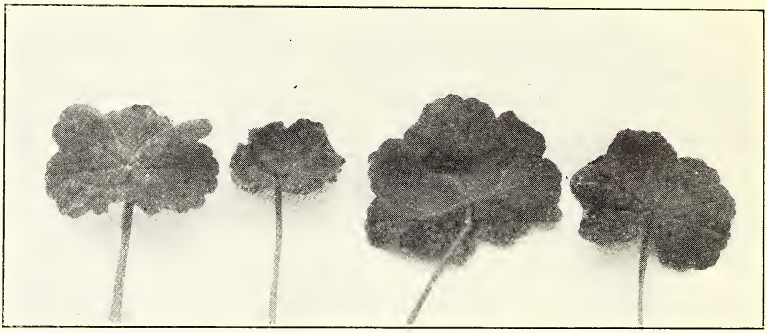

Fig. 1. Toxicity of colloidal and non-colloidal arsenic to geranium leaves. (Second from left). Treatment—50 grams of gum arabic and one gram As_2O_3 per gallon of water, resulting in serious injury. (Third from left), Treatment—One gram of As_2O_3 per gallon of water without gum arabic resulting in slight damage. (Photo by E. J. Kohl).

gum arabic or albumin. The colloidal arsenic compound was added to enough distilled water to make a gallon and the plants were treated by dipping them twice during the application. Five plants were used for each of the different solutions tested. It was found that one gram of the finely divided non-colloidal arsenic in one gallon of distilled water was on the borderline of toxicity as two or three leaves developed some signs of injury within one week after treatment. With this danger zone established, treatments were begun on 50 plants using

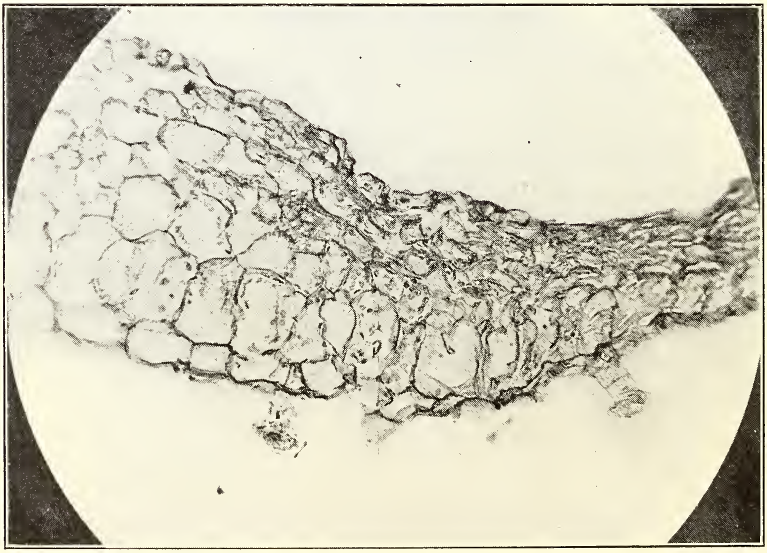

Fig. 2. Geranium leaf section showing normal tissue at left and that which has been injured by application of colloidal arsenic, at right. Photomicrograph by D. C. Cooper.

10 grams of gum arabic per gallon and increasing quantities of arsenic ranging from 0.1 gram to 0.9 gram. These treatments resulted in no injury to the plants. This was followed a week later by using the same quantities of arsenic but five grams of egg albumin were substituted for the gum arabic. This too resulted in no injury to the plants. This was followed by the use of 50 grams of gum arabic and the same quantities (0.1 to 0.9 grams) of arsenic (As_2O_3) as before. Serious injury resulted to all plants receiving 0.3 gram or more per gallon. Thus the addition of 50 grams of gum arabic per gallon caused 0.3 gram of arsenic to be much more toxic to geranium plants than one gram of arsenic without the presence of colloidal matter. The addition of 100 grams of gum arabic only, per gallon, produced no toxic effects to the plants, but some evidence of damage was evident when 0.2 gram of arsenic per gallon were added to the 100 grams of gum arabic solution. It was noted also that a mixture of 100 grams of cane sugar, water and 1.0 gram of arsenic was more toxic than only the arsenic compound. The nature of the injury to the leaves may be noted from figures 1 and 2.

SUMMARY.

These experiments indicate that the toxicity of arsenic is greatly increased by making it colloidal and that 0.3 gram of colloidal arsenic per gallon of water is more toxic to geranium plants than 1.0 gram of arsenic in the non-colloidal form. Thus it would appear that both animal and plant life are more seriously affected by arsenic in the colloidal form than in the non-colloidal condition.

AN IMPROVED TEST FOR ACETONE IN URINE.

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Lieben's test for acetone[1] depends upon the formation of iodoform when potassium iodide, iodine solution, and a few drops of sodium hydroxide solution are added to an acetone containing mixture. The iodoform is recognized by its distinctive odor and, microscopically, by the star, or hexagonal crystals. The test is not specific[1] since both ethyl alcohol and acetic aldehyde also react with these reagents to yield iodoform. This sometimes leads to erroneous results because of alcohol formed through sugar fermentation in diabetic urine.

The difficulty is obviated[2] by substituting ammonium hydroxide for the caustic alkali as proposed by Gunning[3] in a modification of the Lieben Test.

In either test the reaction is much more sensitive if a urine distillate is used. The distillation not only frees the acetone from non-volatile interfering substances, but converts some acetonacetic (di-acetic) acid, if present, into acetone. Protein interferes[4] and, if present, the separation of acetone by distillation or aeration is necessary.

M. Kohlthoff[5] states that 100 mg. each of potassium iodide and chloramine T, 10-20 drops of 4N ammonium hydroxide and 10 cc. of a solution of one part acetone in 10,000 parts of 2 per cent ethyl alcohol when warmed to 60°C. gave an iodoform precipitate in two hours.

The object of our investigation has been to determine (a) whether this reaction could be applied as a specific test for acetone in urine, (b) what urinary constituents or preservatives interfere, (c) if the necessity of distillation, or aeration, of the urine could be dispensed with, and (d) the conditions for attaining the maximum sensitiveness of the reaction.

EXPERIMENTAL.

The acetone used was purified by distilling over anhydrous potassium carbonate. From a constant boiling fraction aqueous and urinary solutions of various concentrations were prepared.

The procedure employed in each experiment was as follows: Two drops (from a medicine dropper) of a saturated solution of potassium iodide, about 0.1 g. of powdered chlorazene[6], and 10-15 drops of 4N ammonium hydroxide[7] were added to 10 cc. of the acetone containing

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[1] A. Lieben, Ann. Chem. u. Pharm. Suppl. 7, 226 (1870).

[2] V. Jaksch, Zeit. f. Klin. Med. 8, 115 (1884).

[3] Gunning, by Bardy, J. de pharm. et de chim. (5), 4, 30 (1881).

[4] Rosenbloom, Jour. Amer. Med. Assoc. 59, 445 (1912).

[5] Kohlthoff, Pharm. Weekblad, 62, 652-5 (1925) ; Chem. Abstr. 19, 17, (1925) ; Chem. Zentralbl. 96, 2, 3, (1925).

[6] Product of the Abbott Laboratories: p-toluene sodium sulpho-chloramide.

[7] Ammonium hydroxide of the specific gravity 0.971 is approximately 4N.

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solution and the mixture placed, for 3 to 5 minutes, in a bath of water having a temperature of 60°C.

The limit of sensitivity of this test for acetone in aqueous solution was investigated with results, as tabulated:

Acetone g.	Water cc.	Odor of Iodoform	Crystals of Iodoform (Time required for the appearance of)
1	500	present	at once
1	2,000	present	at once
1	10,000	present	at once
1	20,000	present	10 minutes
1	25,000	present	15 minutes
1	33,000	present	20 minutes
1	40,000	present	5 hours
1	50,000	present	no crystals
1	100,000	present	no crystals
1	125,000	present	no crystals
1	150,000	absent	no crystals

The delicacy and dependability of this test when applied directly to urine to which acetone had been added were found greatly impaired.

Concentration		Iodoform	
Acetone g.	Urine (normal) cc.	Odor	Crystals
1	500	present	none
1	1000	absent	none

The minimum concentration, therefore, in which acetone can be detected in urine by the above treatment, without distillation or aeration, lies between 1 in 500 and 1 in 1000. The precipitated phosphates interfere with the recognition of iodoform by either color or crystalline form. There was also an odor from the reaction mixture which made it difficult to differentiate the odor of iodoform. The final solutions were of darker color than the urine. This indicated that but little iodine was actually used and that some normal urinary constituent inhibits the formation of iodoform.

The Effect of Preliminary Removal of Phosphates from the Urine.—A test was first made to determine whether or not the addition of ammonium hydroxide before the potassium iodide and chlorazene would have any effect upon the trend of the reaction in a solution of acetone in water, 1 in 5,000. Equal volumes of the acetone solution receiving the reagents in normal and in reverse order yielded abundant and identical quantities of iodoform.

Urine containing acetone, 1 in 1,000, was made alkaline with ammonium hydroxide and the precipitated phosphates removed by filtration. The test applied to the filtrate gave no iodoform.

Other portions of the urine, containing different amounts of acetone, were treated with the magnesia mixture and the test applied to the filtrates. A slight odor of iodoform was detected in the sample having an acetone concentration of 1 in 500; none in that having a concentration 1 in 1,000.

Samples of urine, containing varied amounts of acetone, were acidified with hydrochloric acid and sufficient phosphotungstic acid added for complete precipitation. The precipitate was removed by centrifuging and the clarified liquid made alkaline with ammonium hydroxide. This was again certifuged and the iodoform reaction applied to the clear liquid. The limit of sensitiveness following this procedure was found to lie between 1 in 500 and 1 in 1,000. Neither removal of phosphates nor precipitation with phosphotungstic acid increased the sensitiveness of the reaction.

The Effect of Removal of Urinary Pigments.—Half gram portions of various decolorizing agents were added to 10 cc. portions of urine containing acetone, 1 in 1,000. The mixtures were shaken, filtered and the filtrates subjected to the iodoform reaction with results as follows:

	Decolorizing agent	Iodoform Odor	Iodoform Crystals
1.	none	none	none
2.	"Superfiltchar"[8]	strong	abundant
3.	"Darco"	strong	many
4.	Lloyd's Reagent (did not decolorize)	none	none

The greatest increase in sensitiveness of the reaction followed the treatment with superfiltchar. The minimum amount of this bleaching carbon required to completely decolorize 10 cc. portions of normal urine after shaking one to two minutes at room temperature was found to be 0.4 g. The volume of the completely decolorized filtrate was approximately 6 cc. after the use of 0.4 and 0.5 g. of the carbon.

In connection with the tests executed to fix the maximum delicacy of the reaction in which the odor of iodoform, not the formation of a precipitate, was relied upon, it was observed that an odor slightly suggestive of iodoform was produced when the agents were added to decolorized acetone-free urine and even when the reaction was applied to distilled water. The cause of this odor was traced to the presence in the solutions of ammonium iodide and hypoiodite, normal products of the reaction of iodine with dilute ammonium hydroxide.[9]

The addition of sodium hydrogen sulphite not only neutralized the excess of ammonium hydroxide, but decolorized the final solution; and completely removed the odor suggestive of iodoform.

The limit of sensitiveness of this test for acetone in urine was determined, as follows:[10] To 15 cc. of urine, containing a definite amount of acetone, there was added 1 cc. concentrated ammonium hydroxide and 0.6 to 0.7 g. of superfiltchar. The mixture was shaken for one to two minutes, filtered and 10 cc. of filtrate reserved for the iodoform test.

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[8] Pharmaceutical grade.

[9] Chattaway, Trans., Chem. Soc., 69, 1572 (1896).

[10] This procedure avoided the precipitation of phosphates later and was adopted as standard in the remaider of the experimental work.

Concentration		Iodoform	
Acetone g.	Urine cc.	Crystals	Odor (NaHSO$_3$ treatment)
1	1,000	at once	present
1	3,000	at once	present
1	5,000	within 10 min.	present
1	8,000	within 15 min.	present
1	10,000	within 20 min.	present
1	15,000	none (24 hrs.)	present
1	20,000	none	present
1	40,000	none	present
1	50,000	none	none

The iodoform crystals obtained in the reaction are six pointed stars, not the hexagonal plates characteristic of iodoform crystallized from alcoholic solution. To identify the iodoform, in case the crystals were not well formed, the supernatant liquid was decanted, the precipitate dissolved in little warm alcohol and a few drops of cold water added to effect quick separation of the iodoform. A drop of the precipitate was then examined under the microscope for crystals of iodoform.

Effect of Abnormal Constituents of the Urine.—The substance was added to 15 cc. of a solution of acetone in urine, 1 g. in 5,000 cc. 1 cc. concentrated ammonium hydroxide was added and the mixture shaken with 0.7 g. superfiltchar and filtered. The reaction was applied to 10 cc. of the filtrate.

1. Certain urinary preservatives.

		Iodoform	
Preservative	Preservative quantity of	Crystals	Odor (after NaHSO$_3$)
Blank		present	present
Thymol	0.1 g.	present	present
Xylene	0.3 cc.	present	none
Sodium fluoride	0.2 g.	present	present
Chloroform	0.3 cc.	none	none
Salicylic acid	0.2 g.	present	present

Xylene, when added in the above concentration, interferes with the detection of iodoform by odor. Chloroform inhibits the formation of iodoform because of its retention of the free iodine in solution. When salicylic acid was used more than the usual amount of ammonium hydroxide was added.

2. Dextrose, Beta-hydroxybutyric acid.

		Iodoform	
Substance	Quantity in 15 cc.	Crystals	Odor
Dextrose	3 cc. 2% sol.	present	present
Beta-hydroxybutyric acid	0.1 cc.	present	present

3. Certain synthetic antiseptics and laxatives (or their cleavage products).

Acetone was added, 1 g. in 5,000 cc., to samples of urine passed after the ingestion of, (a) urotropin preceded by sodium acid phosphate, (b) caprakol (hexyl-resorcinol), (c) phenolphthalein. The application of the test to 10 cc. of filtrate, obtained after the usual decolorizing treatment, from each specimen gave a positive result.

4. Protein.

Various amounts of egg albumen were added to aqueous solutions of acetone, 1 g. in 7,000 cc., and 10 cc. portions were subjected to the iodoform test. A Kjeldahl nitrogen determination was made upon the samples which contained just enough protein to completely inhibit the formation of iodoform. From these data the minimum protein concentration preventing iodoform formation from acetone in water solutions, was found to be 0.55 g. per 100 cc.

Different amounts of acetone were added to albuminous (egg albumin) urine. The protein was removed from 15 cc. portions by adding four to five drops of acetic acid and 10 per cent potassium ferro-cyanide solution until precipitation ceased. After 10 minutes the mixture was filtered, the filtrate made alkaline with ammonium hydroxide and shaken with superfiltchar. The iodoform reaction was applied to 10 cc. of the decolorized filtrate. When the acetone concentration was 1 g. in 8,000 cc. urine the precipitate of iodoform appeared within 20 minutes. The minimum concentration of acetone in urine which contains albumin that can be detected by iodoform odor, using this procedure for removal of albumin, was found to lie between 1 g. in 20,000 and 1 g. in 40,000 cc. urine.

The iodoform test was applied to aqueous solutions of di-acetic acid and of beta-hydroxybutyric acid, one drop in 10 cc. water, with negative results. This demonstrates that the "acetone bodies" do not decompose during the operation to yield acetone and that the test is specific for preformed acetone. It was also proven that their presence in a 1 in 5,000 acetone solution did not interfere with iodoform formation from acetone.

Reaction of the Reagents with Acetaldehyde:

The modified iodoform test was applied to 10 cc. of a water solution of acetaldehyde, 20 drops of acetaldehyde in 500 cc of water. A precipitate of iodoform appeared immediately.[11]

Methyl salicylate, sodium salicylate, salol, saliphen, p-cresol, and phenolphthalein are substances given in the literature as interfering with Legal's test for acetone. Lieben's test is given by acetaldehyde and alcohol; it is interfered with by thymol, phenolphthalein and protein. Phenolphthalein and protein interfere with Gunning's iodoform reaction. The iodoform test for acetone described in this paper, when applied to decolorized urine, is inhibited by chloroform and is interfered with by protein. Acetaldehyde yields iodoform by this method and also by the procedure of Folin.

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[11] Twenty cc. of this aldehyde solution were placed in the aerometer cylinder of Folin's apparatus for the determination of acetone in urine and the procedure carried out as given by Hawk (Physiological Chemistry, 8th. Ed. 567). Iodoform crystals were present in the reagent flask within 15 minutes.

Procedure.—

(a) Urine free from albumin.

To 15 cc. of urine, contained in a flask, add about one cc. of concentrated ammonium hydroxide and 0.7 g. superfiltchar, shake for one to two minutes and filter through a dry paper. To 10 cc. of the decolorized filtrate add about 0.1 g. chlorazene, two drops of a saturated solution of potassium iodide, mix and place in water at 60°C. for about five minutes. According to the quantity of acetone, the precipitate of iodoform may appear immediately, or after some hours, or quantities of iodoform too small to constitute a visible precipitate may be readily recognized by the characteristic odor. If a precipitate is not observed, add a slight excess of a saturated solution of sodium hydrogen sulphite and examine as to odor.

(b) Urine contains albumin.

To 15 cc. of urine add three to four drops of acetic acid and 10 per cent potassium ferro-cyanide solution until precipitation ceases. After 10 minutes filter, or centrifuge, and proceed with the clear, albumin-free fluid as directed in (a).

SUMMARY.

1. Superfiltchar removes from urine certain substances which interfere with the production of iodoform from acetone.

2. The iodoform reaction as described is adaptable to the detection of acetone in the urine. When applied to a decolorized urine filtrate, iodoform was detected by odor in a concentration of 1 g. acetone in 50,000 cc. of urine. With a concentration of 1 g. acetone in 10,000 cc. of urine a precipitate of iodoform resulted within 20 minutes.

3. The modified test is not sensitive to alcohol, di-acetic acid nor beta-hydroxybutyric acid, but is sensitive to acetaldehyde.

4. It is interfered with by the presence of protein in amounts exceeding 0.5 g. per 100 cc. The protein may be removed with acetic acid and potassium ferro-cyanide and the decolorizing process then carried out without greatly reducing the sensitivity of the reaction.

5. The reaction is not inhibited nor rendered less sensitive through the presence of the commonly used urine preservatives nor by the synthetics urotropin, hexyl-resorcinol, and phenolphthalein.

A STUDY OF THE AVAILABLE METHODS FOR THE DETERMINATION OF SELENIUM IN ORGANIC COMPOUNDS.

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The existing methods for the estimation of selenium, when applied to the determination of that element in organic compounds, either give results which are inaccurate or involve tedious manipulations.

It has been stated in the literature (1, 2, 3,) and has been verified in this laboratory (4) that nitric acid will oxidize selenium to selenious but not to selenic acid. Therefore the selenium in an organic compound, after treatment with fuming nitric acid in a sealed tube, will be converted into selenious acid and will be accompanied by an excess of nitric acid. Any method of analysis, which entails either the precipitation and weighing of the selenium as the element or the estimation by volumetric reduction of the dioxide, will be interfered with by this nitric acid or by the nitrates which may be formed by the neutralization of the acid.

J. Meyer (5) and later Gutbier and Engeroff (6) found that there is a notable loss of selenium while evaporating solutions of selenious acid on a water bath. This loss is considerable in the presence of hydrochloric acid. F. Konek and O. Schleifer (7) encountered the same difficulty. They also found that efforts to avoid the use of nitric acid as oxidizing agent, by the use of sodium peroxide or by combustion in a bomb in the presence of compressed oxygen, gave unsatisfactory results.

A method, to satisfactorily follow the Carius treatment, either must provide for the removal of the nitric acid without loss of selenium, or must be based on a reaction which will not be affected by nitrates or nitric acid. Several methods (Group I) have been proposed to meet these requirements, but they involve such an increase in laboratory manipulation that a rapid determination of selenium is impossible.

Group I.

Gravimetric methods.—These methods are objectionable either because of the tediousness of the process or because they are not applicable to solutions of selenium dioxide in nitric acid:

1. By the method of Michaelis and Rohmer (8) the mixture of selenium dioxide and nitric acid is boiled for a few hours, with a great excess of hydrochloric acid, under a reflux condenser. After the removal of the nitric acid is completed, the selenium dioxide is decomposed to selenium by heating for a long time with sodium sulphite. The selenium is thus converted into the black modification and is weighed as the element. H. Bauer (9) stated that this method gave good

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results if certain precautions were observed. Lyons and Shinn (10) encountered difficulty in removing all of the nitric acid when fuming nitric had been used in the Carius treatment.

2. The method of Gutbier and Rohn (11) is based on the reduction, by hypophosphorous acid, of selenium dioxide in an alkaline solution to the element. The precipitated selenium is collected, dried and weighed. The authors state that the precipitation is quantitative.

3. The method of Ivanov (12) is dependent on the formation and subsequent decomposition of the compound, $(HCNS)_2H_2SeO_3$. This, Ivanov states, decomposes to give a compact precipitate of selenium which can be more easily collected and weighed than can the selenium which has been precipitated by earlier methods. By this method the mixture of nitric acid and selenium dioxide is evaporated to dryness; a step which causes inevitable loss of selenium. An additional weakness of the procedure is the fact that it consumes an unusually long time.

4. The Perkins method (13) is based upon the reduction of selenium dioxide by hydriodic acid. This is done in the presence of specially prepared electrolytic silver with which the evolved iodine reacts. The percentage of selenium is calculated from the gain in weight of the silver. No precaution for the removal of nitrates is suggested, so this method is not feasible to follow the Carius treatment.

5. Meyer and Garn (14) developed a method which, although it is not gravimetric, will be discussed here because of its similarity to some of the gravimetric methods. It is based upon the colorimetric comparison of the mixture, resulting from the reduction of selenious acid by hydriodic acid, with similar mixtures of known selenium content. They state that the method is not practicable above 0.05 per cent selenium. It is obvious that the presence of nitrates would interfere with the action of hydriodic acid.

6. F. von Konek and O. Schleifer (15) decomposed the selenium organic compound by heating in sulphuric acid, reduced the resulting oxides by means of sulphur dioxide, and weighed the selenium as the element. The objectionable feature of this method is that the amount of heating necessary can not be accurately determined. Excessive heating leads to partial formation of selenium dioxide, the reduction of which in the presence of sulphuric acid "presents difficulties".

7. W. Smith (16) proposed a method which is designed for the removal of an excess of sulphur. This is done by treatment with bromine to form S_2Br_2. The selenium is precipitated with hydriodic acid in the usual manner and weighed as the element. This method, which would be affected by the presence of nitrates, is designed especially for the estimation of selenium in sulphur.

8. In 1923 V. Lenher (17) discussed in a general way the chemical principles utilized and some of the methods employed in the United States for the detection and estimation of selenium and tellurium.

9. Lenher and Kao (18) studied the precipitation of selenium by sulphur dioxide in hydrochloric acid and found that the temperature of the precipitating solutions should not exceed 30°C.

Volumetric methods.—These are unsatisfactory for the reasons given below:

1. The methods of Muthman and Shaeffer (19), which consists of the decomposition of selenious acid by hydriodic acid and subsequent titration with thiosulphate, has been studied by Gooch and Reynolds (20) and found to be inaccurate.

2. By the iodometric method of Norris and Fay (21, 22) the selenious acid is reduced in the presence of hydrochloric acid by an excess of tenth normal thiosulphate, and the excess thiosulphate is titrated with a standard iodine solution. This method, according to Lyons and Shinn (23), gives good results but is interfered with by the presence of nitrates.

3. The indirect iodometric method of Gooch and Pierce (24), according to Moser and Prinz (25), gives good results only when carried out in a distillation apparatus instead of in a flask. In 1924 Congdon and Bray (26) made a critical study of this method and found that the results averaged 0.7 per cent too high.

4. The Fredrich (27) method is based upon the following reaction: $4AgNO_3 + 3Se + 3HOH = 2Ag_2Se + H_2SeO_3 + 4HNO_3$. Since this method presupposes that the selenium is in the form of the element, it is not directly applicable for use after the Carius treatment. Furthermore the authors say that it is accurate only for very low concentrations of selenium.

5. Pellini and Spelta (28) proposed a method based on the reduction of selenium dioxide by hydrazine according to the following equation:

$$SeO_2 + N_2H_4 = Se + 2HOH + N_2$$

They measured the volume of the nitrogen which was evolved and calculated, from it, the percentage of selenium. It is obvious that nitrates would interfere with the reaction.

6. In 1925 Lenher and Kao (29) found that if selenium dioxide, dissolved in a very slight excess of sodium hydroxide solution and treated with tartaric acid, was subjected to the action of hydrazine sulphate for eight hours at 60°C., a separation of selenium and tellurium was effected. Proper temperature control prevented the precipitation of the tellurium.

7. The volumetric estimation of selenium by potassium permanganate in alkaline solution, of Marino (30), is based on the following reaction:

$$2KMnO_4 + 3SeO_2 = K_2O + 2MnO_2 + 3SeO_3$$

The oxidation is carried out in a hot alkaline solution; the mixture is then acidified, and an excess of oxalic acid solution added. The excess oxalic acid is titrated with potassium permanganate and the percentage of selenium calculated from these data. The original method was modified in 1919 by Moser and Prinz (31) in order to repress side reactions, and again in 1924 by Congdon and Bray (32) who state that their modification gives satisfactory results. The presence of nitric acid would interfere with the use of oxalic acid, and thus make this method, which is also quite tedious, impracticable for use following the Carius treatment.

8. Klason and Mellquist (33) proposed a modification of the Norris and Fay method. The selenium dioxide solution, free from air, is just acidified with hydrochloric acid and an excess of potassium iodide added. The liberated iodine is titrated with twentieth normal sodium thiosulphate solution. The conditions forbid the presence of nitrates.

9. The method of Moser and Prinz (34) is based on the same reactions and is subject to the same limitations.

10. In 1922 Rosenhein and Krause (35) determined selenious acid by titrating it to sodium acid selenite with para-nitrophenol as indicator. This would be impracticable in the presence of nitric acid.

11. Losana (36) determined selenium by heating the material to be analyzed with iron powder and decomposing the resulting ferrous selenide by the addition of hydrochloric acid in an atmosphere of hydrogen. The hydrogen selenide generated was absorbed in a solution of zinc acetate and the selenide formed was titrated iodometrically. Losana designed this method for the analysis of ores and inorganic materials. He made no effort to apply it to the analysis of organic compounds.

12. In 1924 Stecker and Shartow (37), who were evidently unaware of the work of Pellini and Spelta, proposed again that method.

13. In 1925 Lang (38) used a modification of the Pellini and Spelta method. He reduced selenious acid in half normal sulphuric acid solution by means of a measured volume of hydrazine solution, and titrated the excess of the hydrazine with an iodate. The use of hydrazine is prohibited by the presence of nitrates.

GROUP II.

Some methods have been proposed for the estimation of selenium, which either avoid the use of nitric acid or successfully remove the nitric acid, or are able to permit its presence in the form of nitrates.

1. By the Frerichs (39) method, the Carius treatment is conducted in the presence of silver nitrate. The resulting silver selenite is then isolated and dissolved in nitric acid and titrated as soluble silver according to Volhard. Frerichs stated that selenium could be estimated in the presence of halogens by boiling the precipitate with dilute nitric acid, weighing the residue of silver halide and estimating the selenium as above.

2. In 1904 Becker and Meyer (40) used alcohol to rinse out the Carius tube and in the isolation of the silver selenite. Bauer (41) was unable to obtain good results with the Frerichs method. However Konek and Schleifer (42) stated that this method gave satisfactory results. It has been observed in this laboratory that the separation of the silver halide and silver selenite is difficult.

3. Lyons and Shinn (43) developed a method by which the nitric acid might be removed without loss of selenium. This then permitted the reduction of selenious acid by standard sodium thiosulphate solution. This was done by twice evaporating, on a water bath, the con-

tents of the Carius tube in the presence of silver or zinc nitrate. An insoluble ammonia compound ($Ag_2SeO_3NH_3$ or $ZnSeO_3NH_3$), which permitted the removal of nitrates by washing, was then formed by twice evaporating with ammonium hydroxide. After decomposition of the ammonia complex by acidification with hydrochloric acid, the resulting selenious acid was estimated by treatment with an excess of tenth normal sodium thiosulphate and subsequent titration with a standard iodine solution. The method has been found in this laboratory to give fairly satisfactory results with halogen-free compounds. However it consumes a great deal of time because of the fact that it is necessary to evaporate the solution to dryness on a water bath six times, and because the removal of nitrates is often very tedious. Nitrates, which are sometimes apparently surrounded by the insoluble silver or zinc selenite, cause errors in the iodometric titration.

4. Grabe and Petren (44) proposed a method which permits the presence of nitrates. However it is designed for the estimation of selenium in minerals and is not directly applicable to the analysis of organic compounds.

5. In 1920 Wrede (45) proposed the combustion of the selenium organic compound with oxygen in a tube in the presence of a platinum catalyst, and titration of the resulting selenious acid with tenth normal sodium hydroxide, with methyl orange as indicator, to sodium acid selenite.

6. In 1926 Reid (46) announced a method for the estimation of selenium in organic compounds, which was based on the fusion of the compound with sodium peroxide in the Parr bomb, and the subsequent precipitation of the selenium as the element.

A criticism of the methods available for the determination of selenium in 1914 was made by Konek and Norwall (47) who concluded that, at that time, there were no satisfactory methods available. In a discussion of the quantitative determination of selenium and tellurium, Lenher (48) said, "The separation of the two elements, selenium and tellurium, is not so perfect as commonly supposed. It is only by a fine distinction in choice of reagents and manipulation that it is possible to perfectly separate the two elements."

7. A review of the above methods shows plainly the need for a simple, rapid and direct procedure for the estimation of selenium. The writers (49) have developed such a method, applicable in the presence of nitrates, when the selenium is in the form of the dioxide or selenious acid; a condition which exists after the Carius treatment of halogen-free, selenium, organic compounds. In the analysis of organic compounds by this method, the contents of the Carius tube are first made alkaline with halogen-free potassium hydroxide solution, then slightly acidified with nitric acid, and finally neutralized by the addition of an excess of pure zinc oxide. This mixture is then titrated with a standard solution of silver nitrate according to Mohr's method for halogen determination, using sodium chromate as an external indicator. This procedure, which has not been successfully applied to halogen containing compounds, gives satisfactory results with halogen-free compounds.

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A QUALITATIVE STUDY OF THE CATALYTIC HYDROGENATION OF THE OXIDES OF CARBON.

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The possibility of synthesizing some such valuable products as methyl alcohol or formaldehyde from hydrogen and carbon monoxide has held the interest of many chemists. Despite the recent successful syntheses of the former product under high pressures in Europe, there still remains, no doubt, considerable speculation as to the possibility of uniting these two gases at lower pressures in the presence of various catalysts. With this in view, there are recorded below the results of experiments in which metallized silica gels were used as catalysts with mixtures not only of carbon monoxide and hydrogen but also of carbon dioxide and hydrogen.

Previous Work.—The rather meager literature on the subject was, until quite recently, confined largely to a discussion of the conditions under which methane, and in some cases ethylene, could be obtained with various catalysts. Among the few who have reported formaldehyde among the products may be mentioned Bach (1), Chapman and Holt (2), Jahn (3), and Calvert (4). Practically all of their reports are lacking either in details or in satisfactory evidence of the presence of formaldehyde. The recent work by Patart and the Badische Company on the synthesis of methanol under high pressures has been reviewed by Lormand (5).

Materials Used.—The catalysts employed in the present work were metallized silica gels prepared by the method of Latshaw and Reyerson (6). While the temperature of the original reduction by this method is about —20°C., the higher temperatures prevailing during their use as catalysts also exerts an influence on the state of the metals in the gels.

The carbon dioxide and electrolytic hydrogen used were of the usual commercial variety, and were sent through the customary purification processes. The carbon monoxide was generated by allowing formic acid to drop slowly into hot concentrated sulfuric acid. It was bubbled through concentrated solutions of potassium hydroxide and of sulfuric acid before being stored in a gasometer.

Analytical Tests Employed.—As is apparent from the statement of the object of the investigation, a satisfactory method for the detection of formaldehyde was highly desirable. For this purpose the resorcin ring test was most commonly used. When complications began to develop, however, in the use of this test, an investigation of several of the other methods discussed by Allen (7) was undertaken. Of these,

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[1] DuPont Fellow, 1925-26.

"Proc. Ind. Acad. Sci., vol. 36, 1926 (1927)."

the phenol test alone seemed to be of sufficient value to justify its being used in the present work.

The resorcin ring test is stated to be also available for methanol, the procedure being to oxidize the alcohol to formaldehyde by means of a hot copper wire as a preliminary step. In the absence of a better method, this test was often made, although it cannot be said to be free from objection in the case of low concentrations of the desired products. The molybdic acid test for alcohols was found to be of no service whatever. Not until the latter part of the investigation was it discovered that the modified Sanglé-Ferrière-Cuniasse (7) test could be used to advantage in testing for methanol.

Experimental Data.—The results of the first series of experiments will be mentioned but briefly. In these, the gases, after passage over the catalyst, were sent through water, which was expected to remove any formaldehyde or methanol formed. This water was then tested for the latter two substances. A large number of combinations of catalyst, temperature and reaction mixture were tried in these early experiments. Much of the work on carbon monoxide was with palladium as a catalyst. Platinum, which is poisoned by the monoxide, appeared to be the most favorable catalyst for a study of the carbon dioxide systems. Entirely negative results were obtained in many of the tests, others were doubtful, while still others gave evidence of being more or less positive. It should be mentioned that the pink rings, when obtained in the resorcin test, were always rather faint. The best tests appeared to result when use was made of mixtures of carbon dioxide and hydrogen in the presence of a new platinized gel.

With the hope of increasing the yield of the desired products, a means of recirculation of the gases was next adopted. A mercury circulator, constructed after the model described by Menzies, Collins and Tyson (8) was inserted into the system. The gaseous mixture, after passage over the catalyst, was, by means of this device, continuously but slowly returned to its original container.

Typical results obtained from the use of this apparatus with a platinum catalyst and an approximately equi-molecular mixture of hydrogen and carbon dioxide are shown in table I.

TABLE 1. Recirculation Experiments with Carbon Dioxide and Hydrogen

Temperature	Length of Run	Color of Resorcin Ring Test for HCHO	Color of Resorcin Ring Test for CH_3OH
110-115°C	23 hr.	Distinct pink	Distinct pink
185°	23	Very faint	Very faint
110°	24	Very faint	Very faint

Since the results appeared to be the same both before and after the attempted oxidation with a hot copper wire, the presence of any alcohol was not demonstrated. The third run was made to verify a suspected poisoning of the catalyst at the higher temperature of 185°, This poisoning was later shown to be attributable to sulfur compounds previously adsorbed by the platinized gel. New samples of the catalyst gave results similar to those shown above.

The tests made for formaldehyde after operation at 110-115° with a carbon dioxide system were the most favorable of any obtained throughout the investigation. Not only were the rings of the proper pink color, but there developed upon standing the cloud of white material which is characteristic of a satisfactory test.

Representative results obtained from the application of the recirculation apparatus to mixtures of hydrogen and carbon monoxide are shown in table II. The catalyst designated as Cu No. 2 was reduced at a much higher temperature than was Cu No. 3. A two to one ratio of hydrogen to carbon monoxide was adopted for this work. Such a ratio is the theoretical one required for the formation of methanol, as is indicated by the following equation:

$$2\ H_2 + CO = CH_3OH$$

TABLE II. Recirculation Experiments with Carbon Monoxide and Hydrogen

Catalyst	Temperature	Length of Run	Color of Resorcin Ring Test for HCHO	Test for CH_3OH
Pd	115-120°	20 hr.	Faint pink	Faint pink
Pd	185	24 hr.	Colorless	Colorless
Pd	30	29 hr.	Not pink	
Pd	100	12 hr.	Colorless	Colorless
Cu. No. 2	185	16 hr.	Green	Deeper green
Cu. No. 2	95	19 hr.	Colorless	Green
Cu. No. 2	160	20 hr.	Faint pink	Green
Cu. No. 3	300	22 hr.	Brownish pink	Yellowish green
Cu. No. 3	190-210	18 hr.	Green	Deeper green
Cu. No. 3	160-170	16 hr.	Yellowish pink	
Cu. No. 3	150	45 hr.	Yellowish pink	Yellowish brown

The phenol test, which was applied after certain of the runs with a copper catalyst, generally yielded the expected pink ring. Only in the last run shown in the above table was the color of the ring of sufficient intensity, however, to approach classification as a satisfactory test.

The appearance of a variety of colors when applying the resorcin test led to an investigation of the results obtained with this test when used with very dilute solutions of various organic substances. Methanol was found to give a pinkish brown ring, which developed a cloud of white material upon standing, while acetaldehyde yielded a brownish green ring. Formic acid and ethyl alcohol both gave faintly pink rings, which did not, however, develop a white cloud. It was also observed that methanol, when oxidized with a hot copper wire, gave rings varying in color from brown to green, and did not give the expected pink one. This observation is worthy of mention in view of the results shown in the last column of table II. The results of tests made when copper was the catalyst tend to indicate, in fact, the strong possibility of more than one substance among the products.

It should also be mentioned that the effluent gases generally had a very pleasant odor. While this odor was not identified, it should not be overlooked, in view of the fact that Fischer and Tropsch (9) have also observed a pleasant odor during similar experiments in which they synthesized various homologues of methane. That such products were being obtained in the present work is not improbable. During the course of a subsequent quantitative study it was demonstrated, in fact, that both saturated and unsaturated hydrocarbons are produced.

After the completion of the work at atmospheric pressure an entirely different apparatus was assembled for the purpose of investigating the same reactions under pressures of from eight to 27 atmospheres. Although the catalyst, temperature, pressure and reaction mixture were varied considerably during this work, better tests than those resulting from experiments at atmospheric pressure could be obtained.

SUMMARY.

1. Attempts to synthesize formaldehyde or methanol at atmospheric pressure have been followed by means of qualitative tests for these substances.
2. The most favorable tests for formaldehyde were obtained when using a platinized gel as catalyst with mixtures of hydrogen and carbon dioxide.
3. With hydrogen and carbon monoxide and a copper catalyst, the evidence seemed to point towards a mixture of products.
4. Pressures varying from 8 to 27 atmospheres gave no indication of being more favorable than one atmosphere for these syntheses.

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SOME THEORETICAL DISCUSSIONS OF HYPNOTICS.

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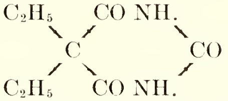
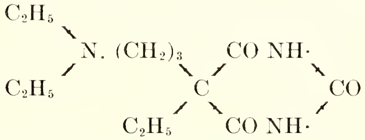
Since the pioneer work of Emil Fischer on the barbituric acids in 1904 and 1905 there has been an enormous amount of research centered about this series, due to the fact that the diethyl derivative was found to have soporific properties. The methylene hydrogen atoms of the barbituric acid ring have been replaced by a large number of alkyl and aryl groups. Substitutions have also been made in the ring, in which compounds the barbituric acids usually function in the enolic modification.

A large number of the derivatives which have been prepared have possessed remarkable hypnotic properties. Along with the soporific properties of the acids there runs another very remarkable characteristic, namely, that of possessing a very marked bitter taste. It seems very evident, however, that the bitter taste and the soporific properties do not wholly coincide.

Veronal (diethyl barbituric acid) has a faint bitter taste, and is also a very effective hypnotic.



But 5-ethyl, 5'-diethyl-amino-propyl barbituris acid has a marked bitter taste, but has no soporific properties.



The author has investigated 30 members of the series and has found that all investigated have the characteristic bitter taste.

There is, in organic compounds at the present time, apparently no constancy in the relation between chemical groups, structure, and taste. Several rules have been formulated which apply for special cases, but which are worthless when applied generally. It seemed probable that if one series was investigated thoroughly, some general conclusions could be drawn concerning the effect of different groups on taste. Taste, of course, is a complex physiological function, and the conditioning factors are so many that conclusions drawn are fraught with errors. The technique used in determining the taste must always be uniform.

It was with the idea in mind of finding out more about taste that the following diffusion experiments were conducted.

Kahlenberg[1] has recently carried on some investigations on diffusion through cholesterol membranes. He has found that the cholesterol

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[1] Phil. Mag. Vol. I., 1926, p. 385.

"Proc. Ind. Acad. Sci., vol. 36, 1926 (1927)."

exhibits an ability to select materials from solution which can diffuse through the membrane. In other words, it functions as a selective membrane. He found the same true for phytosterol.

This proves to be very interesting since cholesterol is thought to be the chief constituent of the animal cell wall, and phytosterol of the plant wall. The presence of these sterols in the cell walls would account for the selective ability of the cell, according to Kahlenberg.

The work of Kahlenberg suggested the possibility of trying such membranes with hypnotics of the barbituric acid series and of thus strengthening or weakening the Meyer-Overton theory of hypnotic action. The Meyer-Overton theory states that soporific properties depend on the water lipoid solubility of the substance in question. This theory, at present the most acceptable of those current, does not seem entirely adequate.

As the source of cholesterol in the work, I used Lanolin (Merck), which is very high in cholesterol and its esters. A very fine grade of white silk was used as the membrane. This was tied over the mouth of a thistle tube and then dipped in warm Lanolin. A very uniform coating of the cholesterol may be obtained by carefully rotating the impregnated silk over a very small flame. The membrane must be tested by filling the thistle tube with nickel chloride, and placing the membrane beneath a solution of ammonium sulfide. If no nickel sulfide is formed after ten minutes the membrane can be considered tight.

Twenty cc. of a 1/10 per cent (quantitative) solution of veronal (diethyl barbituric acid) was poured into the thistle tube bearing the membrane, and the tube lowered into a beaker containing a measured amount of phosphate buffer solution having the same pH as the blood. The membrane is lowered beneath the phosphate mixture, and the diffusion is left to proceed. At intervals of two hours two cc. samples were taken from the phosphate solution, and micro Kjeldahl (Folin-Wu method) determinations were made for total nitrogen. The total nitrogen present gave directly the amount of barbituric acid which had actually diffused through the membrane.

The same was tried with the dimethyl derivative. Dimethyl barbituric acid is ineffective as a hypnotic.

Unfortunately results could not be obtained by the micro Kjeldahl method which would check from experiment to experiment. This was very likely due to impurities in the acid. They were all recrystallized several times, however. Qualitative results showed that the diethyl derivative diffused faster than the dimethyl analogue.

At present the author is working on a colorimetric determination of certain members of the barbituric acid series. If this can be worked out, the diffusion can be measured much more accurately and the diffusion of the barbituric acids into animal cells such as blood cells can be attempted. The complications which arise in using the Kjeldahl method on living cells offer too many difficulties to make the work worth trying.

It is hoped that further work on diffusion will cast some light on the theory of hypnotic action, and, indirectly, offer some explanation of the taste phenomena in the series.

MATHEMATICS AND THE OTHER SCIENCES.

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American universities grant the doctorate in 20 different sciences according to information given out by the National Research Council. To a mathematician naturally the question arises as to how many of these 20 sciences make use of mathematics in some form that requires a knowledge of the calculus for a proper interpretation of certain results. That mathematical knowledge beyond the calculus is necessary for a proper understanding of such sciences as physics, chemistry, astronomy, engineering and meteorology will be granted by all who are sufficiently well acquainted with those sciences, but that certain phases of such sciences as zoology, botany, psychology, anatomy, pathology, physiology and agriculture are amenable to mathematical treatment is probably not so well known. The mathematical developments and applications in some of these sciences will be discussed in this paper, and a few examples of treatment cited, but no attempt will be made to do more than suggest the wide variety of application and to indicate something of the possibilities of future developments.

Some time ago the following fable appeared in *Science*.[1] It is entitled "The Genealogy of Theory."

"Suggestion, an eager Boy, met a winsome Maid, Credulity by name, and begat Plausibility, an enchantress. She mated with a chance acquaintance, Coincidence, and bore him Belief, a stalwart Youth who set out to conquer the World. But across his shield was blazoned the bar sinister. Reason had not consecrated either union."

Mathematics is the science of pure reason and until the facts of any science can be marshalled and subjected to the critical processes of pure reason not much progress of an exact nature can be expected. This does not necessarily imply a mechanistic attitude, but it does imply a most critical attitude. The more nearly mathematical in form a law is stated the more exact it is and the more understandable it becomes, and it can be subjected to further mathematical treatment and interpretation. Some object that the vital processes are not governed by mechanistic laws, and of course no one can decide that with the meager knowledge of the laws of the vital processes now available. Nor is it probable that a science like botany will ever be treated in a formal mathematical way as Spinoza attempted to treat his *Ethics*. But certainly a scientist with a fundamental knowledge of botany and a reasonable working knowledge of mathematics will discover many phases of botany which are governed by mathematical laws. Probably the reason so little is known of the mathematical laws of botany is that

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[1] Science, Vol. 61, (mis.) 1925, p. 567.

"Proc. Ind. Acad. Sci., vol. 36, 1926 (1927)."

very few botanists know any mathematics and almost never is a mathematician trained in botany. But these conditions are changing.

One of the leading college textbooks in genetics[2] states the following: "A knowledge of mathematics is a valuable asset because it is often necessary to subject the data of heredity and variation to mathematical treatment in order to interpret them properly. For the elementary study of genetics, a knowledge of the methods of dealing with simpler algebraic problems is sufficient; for advanced study a knowledge of the differential and integral calculus is highly advantageous." Again, the German biologist Wilhelm His says, "The ultimate aim of embryology is the mathematical derivation of the adult from the distribution of growth in the germ." And D'Arcy W. Thompson, the British naturalist, who has attempted to show the mathematical workings of Nature in his book *On Growth and Form,* says "The living and the dead, things animate and inanimate, we dwellers in this world and this world wherein we dwell, are bound alike by physical and mathematical law." These statements should suffice to show that any natural scientist with sufficient mathematical training will find his research field white to harvest. Helmholtz is a splendid example of such a scientist, for his scientific training in anatomy, physiology, physics and mathematics enabled him to make noted advances in electricity, hydrodynamics, light and sound, some of which he applied in developing instruments of great use in medical diagnostics.

Many of the laws well known to the mathematician, physicist and chemist have numerous applications in the natural sciences. Probably the best known is the compound interest law in which the form of growth is such that the rate of increase or decrease at any instant is proportional to the magnitude at that instant of that which is increasing or decreasing. This law is met with in physics in the study of electric currents and the decrease of radioactivity, and in chemistry where it is known as Guldberg and Waage's law or the law of mass action. Thus $S_t = S_0e^{-kv}$ where $v = t + (t^2/2p)$, where S_t is the area of a wound at time t, S_0 the initial area of the wound, and k and p constants, is the equation representing the healing of wounds. It has been used to study the merits of various antiseptics and dressings, and a serious deviation from the curve is often indicative of infection before the infection becomes apparent otherwise. If bacteria are allowed to grow freely in the presence of unlimited food their number at time t is given by the equation $N = Ce^{kt}$. This law is frequently met with in vegetable growth. The law of mass action is also applicable to the dissociation of oxyhaemoglobin. The growths of animal and human populations have been studied as applications of this law but owing to environmental, economic and other restrictive conditions several modified exponential equations have been used with better success to represent these growths.

In his studies in the morphology of the blood vessels John Hunter found and stated that the angle of origin of the branch vessels varied in such a way that the circulation of blood would be just sufficient for the part. Hess's law assumes that the loss of pressure is mainly due to the friction of the blood stream against the vessel walls and that the pressure varies directly as the length of the vessel and inversely as its radius, that is, $P=\left(\frac{M}{R}+\frac{N}{r}\right)K$, where M and N are the distances of the flow along the main vessel and branch vessel, respectively, and R and r are their respective radii, and K is the factor of proportionality. If now the minimum value of P be determined by means of the calculus, the following relation is found: $\frac{r}{R} = \cos x$, where x is the angle which the branch vessel makes with the main vessel. This relation shows that very small vessels like capillaries come off of larger vessels at practically right angles, branch vessels that are almost as large as the main vessel come off almost parallel to the main vessel, and all vessels of practically the same size come off the same main vessel at the same angle.

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[2] Babcock and Clausen, Genetics in Relation to Agriculture, p. 11.

Again, in the study of the nerves it has been found that if the outer coat or myelin sheath be considered as similar in its function to the insulating coat of a submarine cable, and that if the same law be assumed to hold for the speed of transmission of an impulse as for the speed of signalling along the cable, then the ratio between the radius of the axon or nerve core and that of the myelin sheath is such as to make the speed of the impulse approximately a maximum.

There are numerous other special applications of mathematics to biology. Thus thermodynamical laws may be used in determining the amount of work done by the kidneys. The Van't Hoff-Arrhenius law for the influence of temperature on the velocity of reaction of substances in solution has applications in the conduction of impulses along a nerve, the rate of heart beat, the rhythm of the small intestine, respiration in plants, et cetera. The Schütz-Borissoff law with regard to the action of enzymes is applicable to gastric digestion in the early stages. The muscles fall into several distinct types and the work done by them can be approximately computed by mathematical methods. Still another interesting illustration is the relation between the tension and radius of curvature of a membrane under constant pressure. The thickness of wall is proportional to the tension which in turn is a function of the radius, and the variable thickness of the walls of the heart and uterus, for example, is easily explained by this relation.

So far no mention has been made of Mendelian theory which is based on probabilities and requires a knowledge of the methods of mathematical theory of statistics for a proper understanding of it. The mathematical theory of statistics involves the use of calculus, some differential equations, the laws of probability, the theory of errors, et cetera, and may be applied wherever the number of variables is great and most of the variables are beyond control. It has been used heretofore chiefly in life insurance, educational and psychological tests, genetics and agricultural experimentation as a means of interpreting data and forecasting future possibilities.

Probably the best known American author of mathematical biological studies is Prof. Raymond Pearl, of Johns Hopkins University, whose books *Studies in Human Biology* and *Medical Biometry and Statistics* are real statistical studies. In a recent work, *Elements of Physical Biology*, Prof. A. J. Lotka, of Johns Hopkins University, attempts to apply systematically to certain topics of biology, such as the growth of species and the evolution of living species, the same methods as are used in theoretical mechanics. Another biologist who has made use of mathematical methods is P. Lecomte du Nouy, of the Rockefeller Institute for Medical Research, the results of whose researches are frequently published in the *Journal of Experimental Medicine*. Du Nouy discovered the law for the healing of wounds. The book *Growth and Form* by D'Arcy W. Thompson contains a most interesting collection of illustrations of mathematical laws and curves as found in plant and animal life, and the numerous observations therein noted should serve as a starting point for some most interesting biomathematical research. Another recent book, *Biomathematics*, by W. M. Feldman, contains the solutions of a number of special biological problems, several of which have been used as illustrations in this paper. A number of other investigators are doing work along these lines but no further enumeration will be made here.

One must be cautious in drawing conclusions based on mathematical treatment, for the results are no truer than the fundamental assumptions made leading to their derivations. Gross errors may be made by the novice in the use of mathematical and statistical methods, for the proper interpretation of the results requires more than a mere knowledge of mathematical and statistical formulas. Consequently the best research work will probably be accomplished through the co-operative efforts of the mathematician, physicist, chemist and biologist, for certainly the fields of mathematics, physics, chemistry, biology, and agriculture are too broad for one man to master more than a part of any one of them. The general philosopher has passed along with the spinning wheel, the bootjack and the stage coach. On the other hand, the mathematician need only look about him for applications of mathematics, and as the Talmud has it, "He who knows mathematics and does not make use of his knowledge, to him applies the verse in Isaiah (V, 12), 'They regard not the work of the Lord, neither consider the operation of his hands'."

ENUMERATION OF THE VASCULAR FLORA OF JASPER COUNTY, INDIANA.[1]

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As a resident of Jasper County I have been very much interested in the flora of this prairie region. Upon making a search through the literature concerning county floras, I find that no enumeration of the vascular plants of Jasper County has been published.

This article contains only a partial list of the vascular flora of this county. I am planning to continue the investigation until I have a complete record. Unless otherwise noted the determinations are my own, the doubtful specimens being checked with identified species and varieties in the herbarium of the University of Illinois. The nomenclature, with six indicated exceptions, is that which was sanctioned by the International Botanical Congress, at Vienna in 1905, and as found in the seventh edition of Gray's New Manual of Botany.

The enumeration consists of 102 families, 353 genera, and 662 species and varieties.

I wish to express my sincere thanks to Prof. Wm. Trelease of the University of Illinois for suggestions and aid in preparation of this catalogue and for the use of the herbarium. I appreciate, also, the inspiration given to me by Prof. T. G. Yuncker of DePauw University, the deep interest Mr. C. C. Deam has taken in my efforts, and the aid of Miss Maurie Bailey, who studied the glumaceous families with me.

The specimens upon which the following enumeration is based and the manuscript which includes the data concerning the habitats and the dates and places of collection are deposited in the herbarium of DePauw University. Duplicates of a number of the species may be found in the herbarium of the University of Illinois.

Polypodiceae: *Aspidium Thelypteris* (L) Sw.; *Asplenium Filix-femina* (L.) Bernh.; *Cystopteris Fragilis* (L.) Bernh.; *Onoclea sensibilis* L.; *Pteris aquilina* L.; *Woodsia obtusa* (Spreng.) Torr.

Osmundaceae: *Osmunda cinnamomea* L.; *O. regalis* L.

Equisetaceae: *Equisetum arvense* L.; *E. hyemale* L.

Pinaceae: *Juniperus virginiana* L.

Typhaceae: *Typha latifolia* L.

Sparganiaceae: *Sparganium* sp.

Najadaceae: *Potamogeton foliosus* Raf.

Alismaceae: *Alisma Plantago-aquatica* L.; *Sagittaria graminea* Michx.; *S. latifolia* Willd.

Gramineae: *Agrostis alba* L.; *A. hyemalis* (Walt.) BSP.; *A. perennans* (Walt.) Tuckerm.; *Andropogon furcatus* Muhl.; *Aristida intermedia* Scribn. & Ball; *Avena sativa* L.; *Bouteloua curtipendula*

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[1] Presented at 1925 meeting, but not published in the Proceedings of that meeting because of lack of space.—Ed.

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(Michx.) Torr.; *Bromus hordeaceus* L., var. *leptostachys* (Pers.) Beck; *B. secalinus* L.; *B. tectorum* L.; *Calamagrostis canadensis* (Michx.) Beauv.; *C. inexpansa* Gray; *Calamovilfa longifolia* (Hook.) Hack.; *Cenchrus carolinianus* Walt.; *Dactylis glomerata* L.; *Danthonia spicata* (L.) Beauv.; *Digitaria sanguinalis* (L.) Scop.; *Echinochloa crusgalli* (L.) Beauv.; *E. frumentacea* (Roxb.) Link; *Eleusine indica* Gaertn.; *Elymus striatus* Willd.; *E. virginicus* L.; *Eragrostis Frankii* (Fisch, Mey. & Lall.) Steud.; *E. megastachya* (Koeler) Link; *Festuca elatior* L.; *F. nutans* Spreng.; *F. octoflora* Walt.; *Glyceria borealis* (Nash) Batchelder; *G. nervata* Willd. Trin.; *Hordeum jubatum* L.; *Hystrix patula* Moench; *Koeleria cristata* (L.) Pers.; *Leersia oryzoides* (L.) Sw.; *Panicum albemarlense* Ashe; *P. capillare* L.; *P. dichotomiflorum* Michx.; *P. huachucae* Ashe; *P. implicatum* Scribn.; *P. latifolium* L.; *P. meridionale* Ashe; *P. miliaceum* L.; *P. perlongum* Nash; *P. Scribnerianum* Nash; *P. villosissimum* Nash; *P. virgatum* L.; *Paspalum Muhlenbergii* Nash; *Phalaris arundinacea* L.; *Phleum pratense* L.; *Phragmites communis* Trin.; *Poa pratensis* L.; *Secale cereale* L.; *Setaria glauca* (L.) Beauv.; *Sorghastrum nutans* (L.) Nash; *Spartina Michauxiana* Hitchc.; *Sphenopholis pallens* (Spreng.) Scribn.; *Stipa spartea* Trin.; *Triticum sativum* Lam.; *Zea mays* L.

Cyperaceae: *Carex Bicknellii* Britton; *C. cephalophora* Muhl.; *C. cristata* Schwein; *C. festucacea* Schkuhr, var. *brevior* (Dewey) Fernald; *C. lanuginosa* Michx.; *C. laxiflora* Lam.; *C. lupulina* Muhl.; *C. mirabilis* Dewey; *C. Muhlenbergii* Schkuhr, var. *enervis* Boott; *C. pennsylvanica* Lam.; *C. tribuloides* Wahlenb.; *C. vesicaria* L.; *C. virescens* Muhl.; *C. virescens*, var. *Swanii* Fernald; *C. vulpinoidea* Michx.; *Cyperus ferax* Rich.; *C. filiculmis* Vahl, var. *macilentus* Fernald; *C. rivularis* Kunth; *Dulichium arundinaceum* (L.) Britton; *Eleocharis acicularis* (L.) R. & S.; *E. obtusa* (Willd.) Schultes; *E. palustris* (L.) R. & S.; *Scirpus americanus* Pers.; *S. atrovirens* Muhl.; *S. cyperinus* (L.) Kunth; *S. Eriophorum* Michx.; *S. lineatus* Michx.; *S. validus* Vahl.

Araceae: *Acorus Calamus* L.; *Arisaema triphyllum* (L.) Schott; *Symplocarpus foetidus* (L.) Nutt.

Lemnaceae: *Lemna trisulca* L.; *Spirodela polyrhiza* (L.) Schleid.

Xyridaceae: *Xyris caroliniana* Walt.

Commelinaceae: *Commelina virginica* L.; *Tradescantia reflexa* Raf.; *T. virginiana* L.

Pontederiaceae: *Pontederia cordata* L.

Juncaceae: *Juncus acuminatus* Michx.; *J. brachycarpus* Engelm.; *J. dichotomus* Ell.; *J. interior* Wiegand; *J. marginatus* Rostk.; *J. robustus* (Engelm.) Coville; *J. tenuis* Willd.; *J. Torreyi* Coville; *Luzula campestris* (L.) DC., var. *bulbosa* A. Wood.

Liliaceae: *Aletris farinosa* L.; *Allium canadense* L.; *A. Scorodoprasum* L.; *A. tricoccum* Ait.; *Asparagus officinalis* L.; *Erythronium americanum* Ker; *Lilium canadense* L.; *L. philadelphicum* L., var. *andinum* (Nutt.) Ker; *Maianthemum canadense* Desf.; *Ornithogalum umbellatum* L.; *Polygonatum biflorum* (Walt.) Ell.; *P. com-*

mutatum (R. & S.) Dietr.; *Smilacina racemosa* (L.) Desf.; *S. stellata* (L.) Desf.; *Smilax herbacea* L.; *S. herbacea* L., var. *pulverulenta* (Michx.) Gray; *S. hispida* Muhl.; *Trillium recurvatum* Beck; *T. sessile* L.; *Uvularia grandiflora* Sm.

Dioscoreaceae: *Dioscorea villosa* L.

Amaryllidaceae: *Hypoxis hirsuta* (L.) Coville.

Iridaceae: *Belamcanda chinensis* (L.) DC.; *Iris pseudacorus* L.; *I. versicolor* L.; *Sisyrinchium albidum* Raf.; *S. atlanticum* Bicknell.

Orchidaceae: *Habenaria ciliaris* (L.) R. Br.; *H. lacera* (Michx.) R. Br.

Salicaceae: *Populus alba* L.; *P. deltoides* Marsh.; *P. grandidentata* Michx.; *P. tremuloides* Michx.; *Salix amygdaloides* Anders.; *S. cordata* Muhl.; *S. discolor* Muhl.; *S. longifolia* Muhl.; *S. nigra* Marsh.; *S. rostrata* Richards.

Myricaceae: *Myrica asplenifolia* L.

Juglandaceae: *Carya ovata* (Mill.) K. Koch; *Juglans cinerea* L.; *J. nigra* L.

Betulaceae: *Betula nigra* L.; *Corylus americana* Walt.

Fagaceae: *Quercus alba* L.; *Q. imbricaria* Michx.; *Q. macrocarpa* Michx.; *Q. rubra* L.; *Q. velutina* Lam.

Urticaceae: *Boehmeria cylindrica* (L.) Sw.; *Cannabis sativa* L.; *Celtis occidentalis* L.; *Maclura pomifera* (Raf.) Schneider; *Morus alba* L.; *M. alba* L., var. *tatarica* Loudon; *Parietaria pennsylvanica* Muhl.; *Pilea pumila* (L.) Gray; *Ulmus americana* L.; *U. fulva* Michx.; *Urtica gracilis* Ait.

Santalaceae: *Comandra umbellata* (L.) Nutt.

Aristolochiaceae: *Asarum canadense* L.

Polygonaceae: *Fagopyrum esculentum* Moench; *Polygonum aviculare* L.; *P. Convolvulus* L.; *P. hydropiperoides* Michx.; *P. Muhlenbergii* (Meisn.) Wats.; *P. pennsylvanicum* L.; *P. Persicaria* L.; *P. sagittatum* L.; *P. scandens* L.; *P. tenue* Michx.; *P. virginianum* L.; *Rumex Acetosella* L.; *R. altissimus* Wood; *R. crispus* L.; *R. obtusifolius* L.

Chenopodiaceae: *Atriplex patula* L., var. *littoralis* (L.) Gray; *Chenopodium album* L.; *C. hybridum* L.; *Cycloloma atriplicifolium* (Spreng.) Coult.; *Salsola Kali* L.

Amaranthaceae: *Amaranthus blitoides* Wats.; *A. graecizans* L.; *A. retroflexus* L.

Phytolaccaceae: *Phytolacca decandra* L.

Nyctaginaceae: *Oxybaphus nyctagineus* (Michx.) Sweet.

Illecebraceae: *Anychia canadensis* (L.) BSP.; *A. polygonoides* Raf.

Aizoaceae: *Mollugo verticillata* L.

Caryophyllaceae: *Agrostemma Githago* L.; *Arenaria lateriflora* L.; *Cerastium nutans* Raf.; *C. vulgatum* L.; *Lychnis alba* Mill.; *Saponaria officinalis* L.; *Silene antirrhina* L.; *S. noctiflora* L.; *S. stellata* (L.) Ait. f.; *Stellaria longifolia* Muhl.; *S. media* (L.) Cyrill.

Portulacaceae: *Claytonia virginica* L.; *Portulaca oleracea* L.

Ceratophyllaceae: *Ceratophyllum demersum* L.

Nymphaeaceae: *Castalia odorata* (Ait.) Woodville & Wood; *C. tuberosa* (Paine) Greene; *Nymphaea advena* Ait.

Ranunculaceae: *Anemone canadensis* L.; *A. cylindrica* Gray; *A. virginiana* L.; *Anemonella thalictroides* (L.) Spach; *Aquilegia canadensis* L.; *Ranunculus abortivus* L.; *R. fascicularis* Muhl.; *R. hispidus* Michx.; *R. pennsylvanicus* L. f.; *R. recurvatus* Poir.; *Thalictrum dasycarpum* Fisch. & Lall.; *T. revolutum* DC.

Menispermaceae: *Menispermum canadense* L.

Berberidaceae: *Podophyllum peltatum* L.

Lauraceae: *Sassafras variifolium* (Salisb.) Ktze.

Papaveraceae: *Sanguinaria canadensis* L.

Fumariaceae: *Dicentra Cucullaria* (L.) Bernh.

Cruciferae: *Arabis hirsuta* (L.) Scop.; *A. laevigata* (Muhl.) Poir.; *Barbarea vulgaris* R. Br.; *Brassica nigra* (L.) Koch; *Capsella Bursa-pastoris* (L.) Medic.; *Cardamine bulbosa* (Schreb.) BSP.; *C. pennsylvanica* Muhl.; *Dentaria laciniata* Muhl.; *Erysimum cheiranthoides* L.; *Lepidium campestre* (L.) R. Br.; *L. virginicum* L.; *Radicula Armoracia* (L.) Robinson; *R. palustris* (L.) Moench; *Raphanus Raphanistrum* L.; *R. sativus* L.; *Sisymbrium altissimum* L.; *S. canescens* Nutt.; *S. officinale* (L.) Scop.; *S. officinale* (L.) Scop.; var. *leiocarpum* DC.; *S. Thalianum* (L.) J. Gray.

Crassulaceae: *Penthorum sedoides* L.

Saxifragaceae: *Heuchera hirsuticaulis* (Wheelock) Rydb.; *Hydrangea arborescens* L.; *Ribes gracile* Michx.; *Saxifraga pennsylvanica* L.

Hamamelidaceae: *Hamamelis virginiana* L.

Platanaceae: *Platanus occidentalis* L.

Rosaceae: *Agrimonia gryposepala* Wallr.; *A. mollis* (T. & G.) Britton; *A. parviflora* Ait.; *Amelanchier canadensis* (L.) Medic.; *Crataegus mollis* (T. & G.) Scheele; *Fragaria virginiana* Duchesne; *Geum canadense* Jacq.; *G. strictum* Ait.; *G. virginianum* L.; *Physocarpus opulifolius* (L.) Maxim.; *Potentilla canadensis* L.; *P. monspeliensis* L.; *Prunus americana* Marsh.; *P. pumila* L.; *P. serotina* Ehrh.; *P. virginiana* L.; *Pyrus arbutifolia* (L.) L. f., var. *atropurpurea* (Britton) Robinson; *P. ioensis* (Wood) Bailey; *Rosa humilis* Marsh.; *R. rubiginosa* L.; *Rubus allegheniensis* Porter; *R. hispidus* L.; *R. occidentalis* L.; *R. villosus* Ait.; *Spiraea salicifolia* L.; *S. tomentosa* L.

Leguminosae: *Amorpha canescens* Pursh; *Amphicarpa monoica* (L.) Ell.; *Apios tuberosa* Moench; *Astragalus canadensis* L.; *Baptisia bracteata* (Muhl.) Ell.; *B. leucantha* T. & G.; *B. tinctoria* (L.) R. Br.; *Cassia Chamaecrista* L.; *C. marilandica* L.; *C. nictitans* L.; *Desmodium canadense* (L.) DC.; *D. canescens* (L.) DC.; *D. Dillenii* Darl.; *D. grandiflorum* (Walt.) DC.; *D. illinoense* Gray; *D. nudiflorum* (L.) DC.; *D. obtusum* (Muhl.) DC.; *D. sessilifolium* (Torr.) T. & G.; *Gleditsia triacanthos* L.; *Glycine Soja* Sieb. & Zucc.; *Lathyrus palustris* L.; *L. palustris*, var. *myrtifolius* (Muhl.) Gray.; *Lespedeza capitata* Michx.; *L. hirta* (L.) Hornem.; *L. violacea* (L.) Pers.; *L. virginica* (L.) Britton; *Lupinus perennis* L.; *Medicago lupulina* L.; *M. sativa* L.; *Melilotus alba* Desr.; *M. of-*

ficinalis (L.) Lam.; *Petalostemum candidum* Michx.; *P. purpureum* Vent.) Rydb.; *Psoralea Onobrychis* Nutt.; *Robinia Pseudo-Acacia* L.; *Strophostyles helvola* (L.) Britton; *Tephrosia virginiana* (L.) Pers.; *Trifolium hybridum* L.; *T. pratense* L.; *T. procumbens* L.; *T. repens* L.; *Vicia americana* Muhl.; *V. villosa* Roth.

Linaceae: *Linum medium* (Planch.) Britton.

Oxalidaceae: *Oxalis corniculata* L.; *O. stricta* L.; *O. violacea* L.

Geraniaceae: *Geranium carolinianum* L.; *G. maculatum* L.

Polygalaceae: *Polygala polygama* Walt.; *P. sanguinea* L.

Euphorbiaceae: *Acalypha virginica* L.; *Euphorbia corollata* L.; *E. Cyparissias* L.; *E. maculata* L.; *E. marginata* Pursh; *E. Preslii.* Guss.

Anacardiaceae: *Rhus copallina* L.; *R. glabra* L.; *R. Toxicodendron* L.

Aquifoliaceae: *Ilex verticillata* (L.) Gray.

Celastraceae: *Celastrus scandens* L.

Aceraceae: *Acer Negundo* L.; *A. saccharinum* L.

Balsaminaceae: *Impatiens biflora* Walt.

Rhamnaceae: *Ceanothus americanus* L.

Vitaceae: *Psedera vitacea* (Knerr) Greene; *Vitis vulpina* L.

Tiliaceae: *Tilia americana* L.

Malvaceae: *Abutilon Theophrasti* Medic.; *Hibiscus militaris* Cav.; *H. Trionum* L.; *Malva rotundifolia* L.; *Sida spinosa* L.

Hypericaceae: *Hypericum adpressum* Bart., var. *spongiosum* Robinson; *H. boreale* (Britton) Bicknell; *H. cistifolium* Lam.; *H. gentianoides* (L.) BSP.; *H. mutilum* L.; *H. perforatum* L.; *H. punctatum* Lam.

Cistaceae: *Helianthemum majus* BSP.; *Lechea tenuifolia* Michx.; *L. villosa* Ell.

Violaceae: *Viola lanceolata* L.; *V. palmata* L.; *V. papilionacea* Pursh; *V. pedata* L.; *V. pubescens* Ait.; *V. sagittata* Ait.; *V. scabriuscula* Schwein.; *V. sororia* Willd.

Cactaceae: *Opuntia Rafinesquii* Engelm.

Lythraceae: *Lythrum alatum* Pursh; *Rotala ramosior* (L.) Koehne.

Melastomaceae: *Rhexia virginica* L.

Onagraceae: *Circaea lutetiana* L.; *Epilobium coloratum* Muhl.; *Gaura biennis L.; Ludvigia alternifolia* L.; *L. palustris* (L.) Ell.; *L. polycarpa* Short & Peter; *Oneothera biennis* L.; *O. linearis* Michx.; *O. pratensis* (Small) Robinson.

Araliaceae: *Aralia nudicaulis* L.

Umbelliferae: *Cicuta bulbifera* L.; *C. maculata* L.; *Cryptotaenia canadensis* (L.) DC.; *Daucus Carota* L.; *Eulophus americanus* Nutt.; *Osmorhiza longistylis* (Torr.) DC.; *O. longistylis*, var. *villicaulis* Fern.; *Oxypolis rigidior* (L.) Coult. & Rose; *Pastinaca sativa* L.; *Polytaenia Nuttallii* DC.; *Sanicula canadensis* L.; *S. gregaria* Bicknell; *Sium cicutaefolium Schrank; Thaspium barbinode* (Michx.) Nutt.; *Zizia aurea* (L.) Koch.

Cornaceae: *Cornus Amomum* Mill.; *C. asperifolia* Michx.; *C. paniculata* L'Her.; *C. stolonifera* Michx.; *Nyssa sylvatica* Marsh.

Ericaceae: *Chimaphila umbellata* (L.) Nutt.; *Gaultheria procumbens* L.; *Gaylussacia baccata* (Wang.) C. Koch; *Vaccinium pennsylvanicum* Lam.; *V. vacillans* Kalm.

Primulaceae: *Dodecatheon Meadia* L.; *Lysimachia Nummularia* L.; *L. terrestris* (L.) BSP.; *Steironema ciliatum* (L.) Raf.; *S. lanceolatum* (Walt.) Gray; *S. quadriflorum* (Sims) Hitchc.

Oleaceae: *Fraxinus pennsylvanica* Marsh., var. *lanceolata* (Borkh.) Sarg.; *Syringa vulgaris* L.

Gentianaceae: *Gentiana puberula* Michx.; *Sabatia angularis* (L.) Pursh.

Apocynaceae: *Apocynum androsaemifolium* L.; *A. cannabinum* L., var. *hypericifolium* (Ait.) Gray.

Asclepiadaceae: *Acerates floridana* (Lam.) Hitchc.; *A. viridiflora* Ell.; *Asclepias amplexicaulis* Sm.; *A. incarnata* L.; *A. purpurascens* L.; *A. Sullivantii* Engelm.; *A. syriaca* L.; *A. tuberosa* L.; *A. verticillata* L.

Convolvulaceae: *Convolvulus sepium* L.; *Cuscuta glomerata* Chois.; *C. Polygonorum* Engelm.; *Ipomoea hederacea* Jacq.; *I. pandurata* (L.) G.F.W. Mey.; *I. purpurea* (L.) Roth.

Polemoniaceae: *Phlox bifida* Beck; *P. paniculata* L.; *P. pilosa* L.; *Polemonium reptans* L.

Hydrophyllaceae: *Ellisia Nyctelea* L.; *Hydrophyllum virginianum* L.

Boraginaceae: *Cynoglossum officinale* L.; *Lappula echinata* Gilibert; *L. virginiana* (L.) Greene; *Lithospermum canescens* (Michx.) Lehm.; *L. Gmelini* (Michx.) Hitchc.; *Myosotis virginica* (L.) BSP.

Verbenaceae: *Lippia lanceolata* Michx.; *Verbena angustifolia* Michx. *V. bracteosa* Michx.; *V. hastata* L.; *V. urticaefolia* L.

Labiatae: *Agastache nepetoides* (L.) Ktze.; *Blephilia ciliata* (L.) Raf.; *Hedeoma hispida* Pursh; *H. pulegioides* (L.) Pers.; *Leonurus Cardiaca* L.; *Lycopus americanus* Muhl.; *L. rubellus* Moench; *L. sessilifolius* Gray; *L. uniflorus* Michx.; *Mentha arvensis* L.; *M. arvensis*, var. *glabrata* (Benth.) Fernald; *Monarda fistulosa* L.; *M. punctata* L.; *Nepeta Cataria* L.; *N. hederacea* (L.) Trevisan; *Physostegia virginiana* (L.) Benth.; *Prunella vulgaris* L.; *Pycnanthemum flexuosum* (Walt.) BSP.; *P. virginianum* (L.) Durand & Jackson; *Salvia lanceaefolia* Poir.; *Scutellaria galericulata* L.; *S. lateriflora* L.; *S. parvula* Michx.; *S. parvula*, var. *ambigua* (Nutt.) Fernald; *Stachys hyssopifolia* Michx.; *S. palustris* L.; *S. tenuifolia* Willd., var. *aspera* (Michx.) Fernald; *Teucrium canadense* L.; *T. occidentale* Gray.

Solanaceae: *Datura Stramonium* L.; *D. Tatula* L.; *Physalis heterophylla* Nees, var. *ambigua* (Gray) Rydb.; *P. subglabrata* Mackenzie & Bush; *Solanum carolinense* L.; *S. Dulcamara* L.; *S. nigrum* L.; *S. rostratum* Dunal.

Scrophulariaceae: *Chelone glabra* L.; *Conobea multifida* (Michx.) Benth.; *Gerardia paupercula* (Gray) Britton; *G. pedicularia* L.; var. *ambigens* Fernald; *G. purpurea* L.; *G. tenuifolia* Vahl; *G. tenuifolia*, var. *macrophylla* Benth.; *G. virginica* (L.) BSP.; *Gratiola virgiana* L.; *Ilysanthes anagallidea* (Michx.) Robinson; *Linaria canadensis* (L.) Dumont.; *L. minor* (L.) Desf.; *L. vulgaris* Hill; *Mimulus ringens* L.; *Pedicularis canadensis* L.; *P. lanceolata* Michx.; *Pentstemon laevigatus* Ait., var. *Digitalis* (Sweet) Gray; *Scrophularia leporella* Bicknell; *S. marilandica* L.; *Verbascum*

Blattaria L.; *V. Thapsus* L.; *Veronica arvensis* L.; *V. peregrina* L.; *V. scutellata* L.; *V. serpyllifolia* L.; *V. virginica* L.

Lentibulariaceae: *Utricularia inflata* Walt.

Orobanchaceae: *Orobanche uniflora* L.

Bignoniaceae: *Catalpa bignonioides* Walt.; *C. speciosa* Warder; *Tecoma radicans* (L.) Juss.

Acanthaceae: *Ruellia ciliosa* Pursh.

Phrymaceae: *Phryma Leptostachya* L.

Plantaginaceae: *Plantago lanceolata* L.; *P. major* L.; *P. Rugelii* Dcne.

Rubiaceae: *Cephalanthus occidentalis* L.; *Galium Aparine* L.; *G. boreale* L.; *G. circaezans* Michx.; *G. concinnum* T. & G.; *G. tinctorium* L.; *Houstonia caerulea* L.

Caprifoliaceae: *Diervilla Lonicera* Mill.; *Lonicera Sullivantii* Gray; *Sambucus canadensis* L.; *Triosteum aurantiacum* Bicknell; *T. perfoliatum* L.; *Viburnum affine* Bush, var. *hypomalacum* Blake; *V. Lentago* L.

Cucurbitaceae: *Echinocystis lobata* (Michx.) T. & G.

Campanulaceae: *Campanula americana* L.; *C. aparinoides* Pursh; *Specularia perfoliata* (L.) A. DC.

Lobeliaceae: *Lobelia cardinalis* L.; *L. leptostachys* A.DC.; *L. siphilitica* L.; *L. spicata* Lam.

Compositae: *Achillea Millefolium* L.; *Ambrosia artemisiifolia* L.; *A. trifida* L.; *Antennaria fallax* Greene; *Anthemis Cotula* L.; *Arctium minus* Bernh.; *Artemisia biennis* Willd.; *A. caudata* Michx.; *Aster ericoides* L.; var. *villosus* T. & G.; *A. novae-angliae* L.; *A. umbellatus* Mill.; *Bidens cernua* L.; *B. comosa* (Gray) Wiegand; *B. frondosa* L.; *B. trichosperma* (Michx.) Britton; *Boltonia asteroides* (L.) L'Her.; *Cacalia tuberosa* Nutt.; *Chrysanthemum Leucanthemum* L.; *Cichorium Intybus* L.; *Cirsium arvense* (L.) Scop.; *C. discolor* Muhl.; *C. Hillii* (Canby) Fernald; *C. lanceolatum* (L.) Hill; *Coreopsis lanceolata* L.; *C. lanceolata* L., var. *villosa* Michx.; *C. palmata* Nutt.; *C. tripteris* L.; *Erechtites hieracifolia* (L.) Raf.; *Erigeron annuus* (L.) Pers.; *E. canadensis* L.; *E. divaricatus* Michx.; *E. philadelphicus* L.; *E. ramosus* (Walt.) BSP.; *Eryngium yuccifolium* Michx.; *Eupatorium perfoliatum* L.; *E. perfoliatum* var. *truncatum* Gray; *E. purpureum* L.; *E. purpureum*, var. *maculatum* (L.) Darl.; *E. serotinum* Michx.; *E. urticaefolium* Reichard; *Galinsoga parviflora* Cav., var. *hispida* DC.; *Gnaphalium polycephalum* Michx.; *Helenium autumnale* L.; *Helianthus annuus* L.; *H. divaricatus* L.; *H. grosseserratus* Martens; *H. illinoensis* Gleason; *H. mollis* Lam.; *H. scaberrimus* Ell.; *Heliopsis helianthoides* (L.) Sweet; *H. scabra* Dunal; *Hieracium Gronovii* L.; *H. scabrum* Michx.; *Krigia amplexicaulis* Nutt.; *Lactuca candadensis* L.; *L. scariola* L.; *L. villosa* Jacq.; *Lepachys pinnata* (Vent.) T. & G.; *Liatris cylindracea* Michx.; *L. pycnostachya* Michx.; *L. scariosa* Willd.; *L. spicata* (L.) Willd.; *Parthenium integrifolium* L.; *Prenanthes altissima* L., var. *cinnamomea* Fernald; *P. aspera* Michx.; *Rudbeckia hirta* L.; *R. laciniata* L.; *R. subtomentosa* Pursh; *Senecio Balsamitae* Muhl.; *Silphium integrifolium* Michx.; *S. laciniatum*

L.; *S. perfoliatum* L.; *S. terebinthinaceum* Jacq.; *Silybum marianum* (L.) Gaertn.; *Solidago altissima* L.; *S. caesia* L.; *S. graminifolia* (L.) Salisb.; *S. juncea* Ait.; *S. rigida* L.; *S. speciosa* Nutt.; *S. tenuifolia* Pursh; *S. ulmifolia* Muhl.; *Sonchus asper* (L.) Hill; *Tanacetum vulgare* L.; *Taraxacum erythrospermum* Andrz.; *T. officinale* Weber; *Tragopogon porrifolius* L.; *Vernonia altissima* Nutt.; *V. fasciculata* Michx.; *V. illinoensis* Gleason; *V. missurica* Raf.; *Xanthium italicum* Mor; *X. pennsylvanicum* Wallr.

VAUCHERIA AVERSA.

F. M. ANDREWS, Indiana University.

All of our forms of Vaucheria are plants of exceedingly delicate structure. This together with their generally unicellular structure renders them especially liable to a certain type of injury. Risk of injury in this genus is extensive, but varies in certain species which live in rapidly running water or those which are terrestrial. The author found that filaments of *V. aversa* which were twisted so as to produce sufficient injury, a wall was formed in from two and one-half to four hours. In more severe injury, of this kind, however, a longer time was required for wall formation; for in one experiment where the filaments were twisted almost flat, an average of six hours was necessary.

The species of Vaucheria considered here is not as common as the other species of Vaucheria generally found in this locality.[1] It is a form that has been observed by the writer only once in the last few years and for that reason was not included in the list of algae previously cited.[1] It happens as somewhat smaller fuzzy clumps than are ordinarily recognized in some species found in running water. Low magnification shows that *V. aversa* forms comparatively few branches. These, however, are produced from all sides, rendering its appearance decidedly fuzzy, especially when placed in still water. This fuzzy appearance is less marked in rapidly running water since the filamentous branches are continuously washed in the direction of the flow of the water.

The broad filaments vary somewhat in diameter, some being more and some less than 100 u. as stated by Wolle.[2] The specimens were found by the writer growing in a stream where the velocity of the water was seven and one-half miles per hour. With this velocity of the water a clean green clump of *V. aversa* having a weight of eight grams and a volume of 35 cc. exerted a pull of 5.5 grams (average derived from experiments.) These facts account for the short clumps of filaments and agree with the observations of Klebs. An experiment in which two algal clumps were used each five cm. in length, gave the following result. One clump, in running water with a velocity of seven and one-half miles per hour, grew .5 cm. in length while the other mass, in still water, grew 1.5 cm. under favorable conditions in ten days.

The filaments of Vaucheria are not as easily broken or killed by a gradual continuous pull, as one might suppose, for the writer has shown that a force of 4,400 gravities acting for two hours did not kill the plants nor break the walls although the contents were driven to the centrifugal end of the unicellular filaments. An actively growing filament, without branches, 100 u. in diameter and 3 mm. long weighs

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[1] Andrews, F. M. A List of Algae. Proc. Acad. Sci. 1909; pp. 375-380.

[2] Wolle, F. Fresh Water Algae of the U. S. p. 149, 1887.

"Proc. Ind. Acad. Sci., vol. 36, 1926 (1927)."

about .0009 gr.; therefore the increase in weight in air by the application of 4,400 gravities would be about 4.05 grams. This weight may be reached by gradual application and in a few cases, raised to 5.5 grams before the filaments actually broke, as was ascertained by attaching masses of gypsum of known weight. As would be expected, considerable variation in the strength of filaments of apparently the same size and vigor was demonstrated by the weight method. Part of the time that this plant was under observation, a heavy snow was on the ground and a general air temperature of —10°C. prevailed. The water, where the plants grew however, was not frozen, since it came from a power house and had a temperature of 60°C.

An average temperature of 11°C. surrounding the plants, was maintained at the time of experimentation.

With a temperature of 8°C. in still water, the formation of a few zoöspores was observed in plants from this stream. The zoöspores, however, increased in number when a temperature of 24°C. was attained by artificial means, but complete absence was observed above that point. Klebs found a minimum temperature of 3°C. and a maximum of 26°C. for zoöspore formation in the species studied by him. That running water decreased zoöspore formation, was also shown by Klebs, where in contrast to still water oxygen becomes a variable quantity. The effect of carbon dioxide, however, on zoöspore formation requires further study. Klebs also raises the question of the effect of excreted substances, on zoöspore formation but similar questions follow concerning the various substances given off by roots and other plants. Masses of *V. aversa* brought into the laboratory lived for weeks in the light, without notable change in vigor, when the water was frequently or continually renewed, but produced, under these conditions, only a few zoöspores. When, however, these specimens were darkened for 11 to 48 hours, numerous zoöspores were formed in still water as Klebs has shown for *V. repens*. Too much dependence on zoöspore formation, as influenced by darkness in this plant must not be assumed, however, since in *V. aversa*, and in other species of the genus, only a few or no zoöspores may be formed, at times. No certain experimental data has been ascertained that offers a satisfactory explanation for this.

An interesting fact was the large amount of oil that the specimens of *V. aversa*, here discussed, were able to stand. This oil came from the power house, above mentioned, in large quantities. The plants when taken to the laboratory were washed at first in a large amount of slowly running water for two days, and at other times for several hours on each of several subsequent days. This washing removed most of the large amount of densely adhering dirt. *V. aversa* resembles therefore, in this respect, *V. clavata*, which according to Kerner may collect and hold 100 times its weight of mud on the filaments of a mass. This mud is arrested, however, only by the dead plants. The washing failed to remove a considerable quantity of the oil which could be seen in clear droplets adhering to the filaments. The submerged form of this and other algae had no oil attached. Of the zoöspores that were formed when the plants were darkened for 11 hours, some did not germinate but others began to germinate in 5 to 10 hours. As usual one or two tubes were produced. In some other cases three or four tubes were produced, but in one spore, five tubes, normal in all respects, were sent out.

The chloroplasts of *V. aversa* were unusually numerous. Those filaments on the upper side of the clumps were crowded with chloroplasts. Frequently the ends of the filaments which are often more or less clear were very densely crowded with chloroplasts to the very tip. The filaments near or on the under side of the mass of *V. aversa*, showed about one-fourth the number of chloroplasts of the filaments on the upper side. An estimate of a piece of a crowded filament, exposed to light from the top side of a mass, showed about 12,000 chloroplasts, while a similar piece of a filament from the under or shaded side was estimated to have only about 3,000. This recalls the considerable difference between the number of chloroplasts in palisade cells which is often more than four times those of the spongy parenchyma of the same organ, as shown by Haberlandt. A comparison often shows 10 to 12 times the chloroplast surface exposure for *V. aversa* as for *Spirogyra longata*, which has but one chloroplast. This difference, however, would not be so great in a multi-chloroplast cell of Spirogyra.

A LIST OF ALGAE OF MONROE COUNTY, INDIANA II.

F. M. ANDREWS, Indiana University.

In the 1909 "Proceedings of the Indiana Academy of Science" the writer[1] published "A List of Algae" most of which were found in Monroe County, Indiana. At that time 187 species were recorded. Since 1909 the writer has recorded other species of algae from Monroe County, Indiana, that has come to his attention, and append them in the following list.

It is clear that no complete list of algae, or other plants, may be made by the observations of a single year. The varying conditions of moisture, light, nutrition, temperature and other factors render it possible or impossible for the various types to appear. The different combinations of these conditions cause, at times, the meager development of only a few species or a prolific growth. Or, these conditions may cause repetition of the appearance or disappearance of the various forms in the same year or part of a year. *Vaucheria aversa*, which has occurred only once in the immediate vicinity of Bloomington in the last few years, constitutes a striking example of an algal form illustrating the influence of the untenable conditions that have prevailed over the greater part of a series of years. The same is true of other forms not mentioned heretofore for this county.

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[1] Andrews, F. M. Proc. Acad. Sci. 1909; 375-380.

In order to procure some of the small forms for convenient observation, it is necessary to filter large amounts of the water containing them. This is best accomplished by using a very large funnel having a stem about one cm. long. The diameter of the funnel stem may be reduced by means of a drawn out, closely fitting, short glass tube attached by rubber tubing. The filter paper should be placed on the lower end of this tube, and supported on the outside by a small meshed copper wire gauze-thimble. This thimble, if loose, may be held to the tube, by means of a rubber band. Gentle agitation of the water in the upper part of the funnel, by means of an electric stirring apparatus, is advisable to prevent considerable settling of small specimens on the sides of the funnel. This occurs to a very noticeable degree even on the smooth glass sides of a 60° funnel when stirring is not used. If filter paper is used in the funnel in the usual way, many specimens will be lost even with stirring, and practically all, if the water is left unstirred, and few specimens are present.

Careful centrifuging of a quantity of water containing small specimens usually gives favorable results. The force applied need not be intense, but should be continued over a considerable period of time. A slightly conical and rather thin-walled oscillating glass tube of 10 to 15 cc. capacity should be used. When the centrifuging is complete, the specimens will be in the narrow end of the tube whose internal diameter should be about .5 cm. This end can then be cut off rendering easy access. A glass tube of not too large bore, which is held in sections by rubber tubing and can be quickly lengthened or shortened, is convenient for either shallow or rather deep water. It can be operated either as an open end tube above the water or by means of a rubber bulb. It has the additional advantage, namely that the collector is able to make collections from definite areas or spots in clear water.

The writer has scarcely paid any attention to varieties, since the species determinations are sufficiently accurate and are not so likely to lead to doubtful enumeration as may easily occur in a genus, for example, like Xanthidium. Only two extra species of diatoms has been recorded, but a considerable number of desmids not mentioned in his former list are included in this paper. The total number of species recorded in this contribution number 88. This together with the number of his former list makes 275 thus far found by the writer for the territory mentioned.

The following species were found:

Docidium Trabecula, D. verticillatum, D. truncatum, D. Woodii, D. tridentulum, Closterium nasutum, C. decussatum, C. parvulum, C. Moniliferum, C. Dianae, Penium closteriodes, P. spirostriolatum, P. navicula, Sphaerozosma filiforme, S. excavatum, Tetmemorus giganteus, Calocylindrus curtus, Cosmarium Botrytis, C. pyramidatum, C. moniliforme, C. Meneghinii, C. biretum, C. coelatum, C. speciosum, Xanthidium fasciculatum, Euastrum ansatum, E. Pokornyanum, E. ventricosum, E. circulare, E. Elagans, E. multilobatum, Micrasterias fimbriata, M. pseudofurcata, M. muricata, Staurastrum aristiferum, S. avicula, S. crenulatum, S. punctulatum, S. pentacladum, Pediastrum angulosum, P. sim-

plex, P. Strumii, Arthrodesmus incus, A. octocornis, Hyalotheca mucosa, H. undulata, Gonatozygon asperum, Spirotaenia obscura, S. bryophila, Mesotaenium micrococcum, M. Clepsydra, Gloeocapsa magma, Chroococcus turgidus, Calathrix gypsophila, C. orsiniana, Tolypothrix rupestris, T. flaccida, T. pulchra, Scytonema calotrichoides, S. gracile, S. turfosum, S. cortex Sirosiphon compactus, Hapalosiphon Braunii, H. tenuissimus, Nostoc rupestere, N. coeruleum, N. muscorum, Anabaena stagnalis, A. variabilis, Spirogyra Elongata, S. inflata, S. quadrata, S. dubia, S. adnata, S. rivularis, Zygnema stellium, Z. cruciatum, Zygogonium parvulum, Z. pectinatum, Scenedesmus rotundatus, Ulothrix Zonata, U. aequalis, Cladophora fluitans, Oedogonium undulatum, O. irregulare, Bulbochaete crenulata, Stigeoclonium Thermale, Oscillaria major, O. imperator, O. Elegans, O. natans, O. nigra, Conferva punctalis, Vaucheria aversa, Chroolepus aureus, Rhizoclonium fontinali, Polyedrium minimum, Porphyridium cruentum, Synedra valens, Cocconeis pinnularia.

REVERSION IN TRILLIUM.

F. M. ANDREWS, Indiana University.

It has long been well known that the genus Trillium frequently shows monstrosities of various kinds and degrees. The writer, among others, has called attention, on several occasions, to some of these variations and has cited the chief literature on the subject. It is therefore not the object of this paper to call special attention to these well known deviations, but to indicate the character and time of reversion to the normal condition.

Of the species of Trillium with which this paper is concerned, the writer has observed least tendency to deviation from the normal, in *T. nivale.* This fact was confirmed by an observation extending over a period of 23 years in undisturbed conditions, where only one case of pyllody was produced. During that period, however, a considerable number of variations in *T. sessile, T. recurvatum* and *T. erectum* were observed in the vicinity of the cultivated and uncultivated specimens of *T. nivale.*

It is comparatively rare, under ordinary conditions, that plants in the wild or uncultivated state are apt to be left undisturbed over a period of years sufficient for continuous observation and termination of an experiment, such as this one. However, this was done in an adequate number of specimens in the natural habitat, to establish the points at issue. More convenient and continuous observation of these points were also attained by transplanting a considerable number of specimens representative of the facts here involved. The conditions under which the transferred specimens of the species of Trillium were grown were normal, and in one case, has extended over a long enough period to be convincing.

The short root stalk contains sufficient food to produce more than one year's aerial stems and in fact a considerable portion of this underground part may be carefully removed on transplanting with no adverse effect on the aerial parts. It is by no means unusual to observe two and sometimes three or more stems sent up from one root-stalk. For example, each of three rhizomes of *T. sessile* produced two stems having four and five parts in the flower and leaf whorls. Another rhizome of the same species sent up two stems one of which had the usual number of leaf flower parts, while the flower of the other stem on this rhizome had five leaves and five parts in each flower whorl. Other multi-stemmed rhizomes presented various numerical differences. The reversion of the abnormal specimens to the normal condition was, in all of the many cases observed, eventually complete, as to the size of the plant, to the flowers and in all other respects. This was also true of the flowers of *T. recurvatum*, in some specimens of which, only petal-like parts were present and even where no vestige of reproductive parts were observable. The specimens of *T. sessile* showing abnormalities were frequently below normal size.

That the reversion to normal has a definite time limit, is a point of interest. In most of the abnormal specimens, all of the aerial stems, leaves and flowers, which were produced the second year, were perfectly normal. However, in some specimens, this was not the case. Only three specimens of *T. sessile* and one specimen of *T. recurvation* showed any tendency not to become normal after the first year of abnormality and to deviate to any degree from the ordinary course of development. This abnormal condition continued in both *T. recurvatum* and also in *T. sessile* for two years. The third year and thereafter, they produced perfectly normal flowers and leaves. Where a difference in size of the plants was detected this difference disappeared in all cases at the end of the first year after abnormality. Of the four species studied, this difference in size was most frequently observed in *T. sessile*. An interrupted experiment on monstrosities in *T. erectum* would probably have shown a similar return to normal conditions.

The various statements made with reference to abnormal flowers in Trillium, based on chance observation, or over a short period of time, have heretofore left certain points unanswered. These can therefore be determined, for this genus of plants, only when extended over a considerable range of years, under suitable conditions and regular inspection, as has been briefly set forth in this paper. Of the four species of Trillium observed by the writer, for the most part over a long period of time, *T. nivale* is the least inclined to deviations from the normal, both in the wild and cultivated state.

LYCOPODIUM COMPLANATUM.

F. M. ANDREWS, Indiana University.

Plants sometimes disappear from certain locations and at times reappear in the same place or in a region somewhat removed from their former habitat. Either of these cases of reappearance may of course follow the usual method of reproduction *in situ* or by reproduction followed in the second case, by some form of dissemination. But at times the disappearance in a region of former growth is permanent so far as that area is concerned, due to a change of conditions which even though apparently slight or generally unnoticed makes further growth of the former plant impossible. Some plants are especially sensitive to a small change in any growth factor while other plants are not displaced even by very considerable alteration of one or more of the various conditions usually prevailing. When an attempt is made to transplant plants we find this is accomplished with no difficulty whatsoever in the case of certain species, with fair success in others, while in some species of plants transplanting without killing the specimen is only attained with great difficulty or may be totally unsuccessful.

A plant that is easily killed by a slight change in the external conditions is Lycopodium. It is also difficult to transplant with safety. Kerner has shown this to be true of *Lycopodium inundatum* which lived "only a short time in a garden even though the clods of peat, in which their roots are imbedded are transplanted with them."

Lycopodium complanatum, recently found in Monroe County, Indiana, illustrates the above mentioned points. This species is, of course, known to occur in Indiana, but never in very large quantities or very extensively in this region. About 30 years ago the writer was accustomed to observe this plant on the western slopes of several deep ravines about two miles northeast of Bloomington, Indiana. The hillsides, where it grew, were covered with deciduous trees, such as oak and beech of considerable size and which grew rather densely. No pine trees grew in that vicinity. It is not confined therefore to woods composed of trees belonging to the pine family. After some years *L. complanatum* disappeared from the above mentioned region. This was not due to animals, the removal of timber, or to other apparent reasons. The other forms of plant life thereabouts continued to grow as before in that area and there was no evidence to show in any way that the Lycopodium had been crowded out. It has not been found in the area referred to at any time during the past 30 years.

Three years ago a plant was brought to the writer for identification. He saw at once that it was *L. complanatum* and on inquiry was informed concerning the place where it was growing. This was found to be about eight miles northwest of the region where the writer had formerly seen the plant growing as above reported. As before mentioned, it grows on a western hillside in woods consisting mostly of oak and gum trees.

This plant occupies but one small area, trailing over an area about 75 feet in diameter, in the vicinity of a small sour gum tree. At present the plant does not seem to be as vigorous or as dense as when it was observed three years ago. This is apparently due in large measure to an increased crowding by other plant forms which did not prevail when first observed. It grows on private grounds and the intention is to protect it in the future. This plant therefore which is common in many places, is now rare in this county and at present is known to exist in this vicinity only in the area above mentioned.

ON THE CONTINUED GROWTH OF CERTAIN FERN PROTHALLIA.[1]

DAVID M. MOTTIER, Indiana University.

Prothallia of *Osmunda claytoniana* and *Matteuccia nodulosa* have been grown upon soil for three and one-half and four years, respectively, under cultural conditions which prevented the production of sporophytes. When an occasional sporophyte appeared it was amputated in such a manner as not to injure the gametophyte.

Prothallia thus grown branched both dichotomously and by the production of lateral shoots or proliferations. Proliferations, large and small, develop from the margins, from both surfaces of the midrib, and from the older proximal tissues, as well as from the growing point or apical sinus.

In older prothallia archegonia may be developed from both upper and under surfaces. In such prothallia antheridia are produced chiefly upon small marginal proliferations, or upon small granular protuberances on older parts. In some cases small protuberances are produced along the midrib on the upper side. Such protuberances bear many archegonia.

The cell walls in older parts of the midrib are relatively thick. They are marked by numerous pits varying in size.

Spine-like processes developed from near the growing point in a few prothallia of *Matteuccia nodulosa.* These outgrowths dried up as the prothallia became older. Apogamous sporophytes did not develop in any case.

If sporophytes are not produced, the continuation shoots of the prothallia of the two species in question seem to be able to continue growth indefinitely.

ON THE OCCURRENCE OF AN ENDOPHYTIC FUNGUS IN THE PROTHALLIA OF OSMUNDA CLAYTONIANA L.

DAVID M. MOTTIER, Indiana University.

The presence of endophytic fungi in the non-chlorophyll-bearing, subterranean parts of the gametophytes of certain Ophioglossaceae and Lycopodiaceae is a well-known and expected phenomenon. In ferns with green prothallia, however, the phenomenon is much less common. Of these Campbell (Am. Nat. 62:154-165. 1908) has enumerated the following: *Marattia Douglasii* Baker, *Kaulfussia aesculifolia* Bl., *Angiopteris evecta* Hoffm., *Gleichenia polypodioides* Sm., *G. dichotoma* Willd., *G. laevigata* Hooker, *G. pectinata* Presl., and *Osmunda cinnamomea* L.

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[1] Summary. The paper in full will appear in the Botanical Gazette.

A brief histological study of the continuation shoots of three and one-half year old prothallia of *Osmunda claytoniana* L. has enabled the writer to add this species to the list. A large number of specimens have not been examined up to the present, and the writer is not able to say whether the presence of the endophyte is general or only occasional in the prothallia of this species. Campbell states that the endophyte appeared commonly in *O. cinnamomea*, but it could not always be found. In the limited number of prothallia of *O. claytoniana* subjected to histological study the endophyte was found in all but one. As stated in the foregoing, the endophyte occurred in prothallia of unusual age, grown under controlled experimental conditions, which, however, were as nearly like those out of doors in summer as it was possible to maintain.

Similar prothallia of *Matteuccia nodulosa* Fernald (*Onoclea Struthiopteris*), though some months older, did not reveal the presence of an endophyte, but it is possible that an endophyte may be present also in this species. In *Osmunda claytoniana* the fungus seemed to occupy circumscribed areas much as do colonies of Nostoc in the gametophyte of Anthoceros. The region containing the fungus may be midway between lower and upper surfaces of the prothallium, or nearer the lower surface. Whether the infected areas were in any way united into a continuous layer cannot be stated at present.

The fungus seems to belong to the Phycomycetes. The structure and appearance of the fungus agrees closely with that figured by Campbell (1. c., p. 162, fig. 3 B) for the endophyte in *O. cinnamomea*. It consists of rather large, tubular, branched, and multinucleate filaments that pass from cell to cell, apparently through the pits in the cell walls. The cell walls of the midrib in older parts of the prothallia of *O. claytoniana* in question are marked by numerous rounded or elongated pits that vary considerably in size. It is through the larger of these pits that the hyphae pass from cell to cell.

Conidia were not found in the preparations. In cells containing the fungus the plastids differed in appearance from those in non-infected cells. They seemed to be densely granular, and stained uniformly. No starch inclusions were present in them, and in this respect the plastids contrasted noticeably in appearance with those of non-infected cells. The infected cells were much poorer in cytoplasm. In some cases the nuclei seemed to be normal, but in many cells near the center of the infected region, some of the nuclei were ameboid in form, and appeared abnormal in structure.

The fungus was found in some of the rhizoids, so that it is probable that it gained entrance through them.

The prothallium does not seem to suffer in any appreciable degree from the presence of the endophyte, while there can be no doubt that the fungus receives nourishment from the prothallium. Whether there is a symbiotic relation existing between the two, further study must determine.

INDIANA PLANT DISEASES, 1925.[1]

Max W. Gardner,[2] Purdue University.

This is the seventh of a series of annual summaries[3] of the plant disease situation in Indiana. No claim for completeness is made.

The weather conditions of this season are summarized graphically in figure 1. The warm April favored fire blight of apples and the drouth in April and May greatly reduced the severity of apple scab, rust, and blotch, cherry leaf spot, and wheat stem rust. The hot weather of June and early July favored to some extent the Fusarium wilt diseases. Frequent rains during the summer combined with the very heavy rainfall and high temperature in September resulted in severe losses due to Septoria leaf spot and early blight of tomatoes, cantaloupe leaf blight, watermelon anthracnose, peach brown rot, and apple bitter rot.

The late frost in May killed most of the homegrown tomato plants and resulted in the use of over 100,000,000 southern grown plants in Indiana. The early freeze in October ruined many apples on the trees, and sweet potatoes not yet dug. High winds in the spring necessitated replanting of many onion fields in the Kankakee Valley a month late and the delayed maturity of these fields combined with the very wet fall weather resulted in heavy losses due to fungus discoloration of the outer scale.

Alfalfa.—Leaf spot caused by *Pseudopeziza medicaginis* was widespread. J. L. Weimer found the leaf blotch caused by *Pyrenopeziza medicaginis*, the bacterial blight caused by *Pseudomonas medicaginis*, and the root rot[4] caused by *Aplanobacter insidiosum* near Lafayette, and crown wart[5], caused by *Urophlyctis alfalfae* near Madison, Indiana. This is the first record of crown wart east of the Rocky Mountains. Mains reported rust (*Uromyces medicaginis*) serious in the fall.

Apple.—Scab, caused by *Venturia inaequalis*, was not serious because of the dry weather in April and May. The first fruit infection was noted May 15, at Vincennes. Good control with sulphur dust

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[1] Contribution from the Botanical Department, Purdue University Agricultural Experiment Station.

[2] The writer wishes to acknowledge the co-operation of H. S. Jackson, E. B. Mains, G. N. Hoffer, C. T. Gregory, J. B. Kendrick, C. L. Burkholder, F. P. Cullinan, C. E. Baker, H. D. Brown, Monroe McCoun, F. C. Gaylord, C. L. Porter, Harry Dietz, B. A. Porter, and Leslie Pierce.

[3] Gardner, Max W. Indiana plant diseases, 1919. Proc. Ind. Acad. Sci. 1919: 135-156. 1921. Indiana plant diseases, 1920. Same 1920: 187-208. 1921. Indiana plant diseases, 1921. Same 1923: 163-201. 1924. Indiana plant diseases, 1922. Same 1923: 202-211. 1924. Indiana plant diseases, 1923. Same 1924: 297-313. 1925. Indiana plant diseases, 1924. Same 1925: 237-257. 1926.

[4] Jones, Fred Reul. A new bacterial disease of alfalfa. Phytopath. 15:243-244. 1925.

[5] Weimer, J. L. Crown wart of alfalfa in Indiana. Phytopath. 15:807. 1925.

"Proc. Ind. Acad. Sci., vol. 36, 1926 (1927)."

applied at weekly intervals was reported by Mr. Howard Johnson, an orchardist at Mooresville.

Blotch, caused by *Phyllosticta solitaria,* was much less serious than usual because of the dry weather in May. The first fruit infection was noted June 11, in Knox and Lawrence counties. While tests made by Kohl at Lafayette showed that all infection occurred between five and eight and one-half weeks after petal-fall, spray tests[6] on the Duchess variety at Mitchell showed that the 2-, 4-, and 6-weeks spray schedule was fully effective and that an 8-weeks spray was superfluous. In addition to varieties previously listed as susceptible, infection was noted on Baldwin fruit and on both twigs and fruit of the Cortland variety.

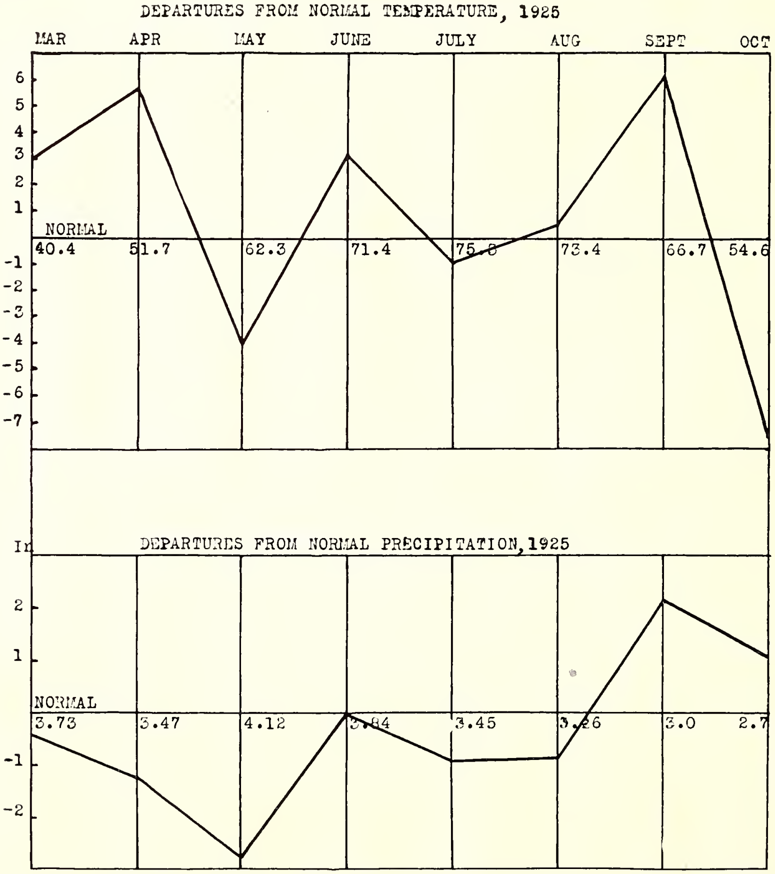

Fig. 1. Departures from normal temperature and precipitation based on monthly averages supplied by J. H. Armington in Climatological Data.

That canker eradication in young orchards effects a successful control of the blotch disease is indicated by the fact that in two young Oldenburg orchards (Simpson orchard, Vincennes) in which the eradication campaign was commenced in 1922, test plots from which the 4-weeks and 6-weeks sprays were omitted this season remained free from infection. In one orchard 21 trees were left unsprayed and on July 10, 5,758 apples on or under these trees were examined and no blotch was found. In the other orchard, 87 trees were left unsprayed and an examination of all the fruit (9,274 apples) on these trees revealed no blotch lesions whatever. While this was a mild blotch year, abundant infection occurred in unsprayed Oldenburg trees and these results are considered highly significant of two facts, (1) that canker eradication is feasible and worth while, and (2) that there is little or no long distance spread of blotch infection.

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[6] Gardner, Max W., Greene, Laurenz, and Baker, Clarence E. Spraying tests for the control of apple blotch. Trans. Ind. Hort. Soc. 1925: 134-147. 1926.

In one Indiana nursery, Dietz found blotch infection on stock grafted on French seedlings but the cankers were confined to the portions above the graft and hence were of domestic origin.

Black rot, caused by *Physalospora malorum*, was less prevalent than usual and was as a rule secondary to scab or blotch lesions, insect injury, hail injury, and growth cracks. Some calyx-end infection was observed. Leaf infection was observed as early as April 23, on Transparent and Rome. Dietz found the black rot fungus as a secondary invader of fire blight lesions in nursery stock.

Fire-blight was more serious in southern Indiana than it was in 1924 but not as bad as in 1923. It became conspicuous the first week in May and was most destructive on Jonathan and Transparent. Blossom blight was noted on Grimes and Stayman and was reported severe on the King variety in LaPorte County. McCown found leaf and fruit infection on Rome in Perry County. The leaf invasion had occurred through the petioles and had apparently progressed out along the veins. In the block of young Oldenburg trees in Knox County to which blight seems to be carried from a neglected pear orchard about a mile distant, very little fire blight was noted this year, perhaps because the pears blossomed two weeks before the Oldenburg trees rather than simultaneously with them as in 1924.

Rust (*Gymnosporangium juniperi-virginianae*) was much less prevalent than in 1924, probably because of the dry spring. The disease was reported from five counties in the southern end of the state. Leaf infection was observed on Jonathan, Rome, and Stayman, and calyx-end fruit infection of Rome and Delicious was found.

Bitter rot, caused by *Glomerella cingulata*, was worse than usual owing, probably, to the rather frequent rains in the late summer and early fall. So far as is known this disease has been a serious factor only in southern Indiana, and in only a few commercial orchards.

The first lesions were observed July 6, by B. A. Porter in Knox County. The disease was very destructive as early as the first week in August, and occurred on Jonathan, Grimes, Transparent, Gano, Collins, Ortley, and Ben Davis. In one mildly infected orchard, bitter rot was confined to four trees, three Grimes and one Ben Davis. In such cases the growers usually pick the diseased fruit from the tree as soon as it is noticed. Despite careful search, cankers as a source of infection have not been found.

In a badly infected Grimes tree in Knox County, some of the fruits showed large lesions at the stem end and it was found that the fungus in such cases sometimes grows up through the fruit pedicel into the twig. The bitter rot fungus was cultured from the basal end of such pedicels. The fungus may thus gain entrance to the twig, and in addition may prevent normal abscission of the fruit with the result that the rotted fruit or mummy remains hanging in the tree as a source of infection for the next year. Schneiderhan[7] in Virginia has pointed out the importance of such pedicel infection and has found that even when such fruits do drop off the pedicel is apt to remain attached to the twig and serve as a source of future infection.

The rot caused by *Phytophthora cactorum* was found in fallen fruit under a few Grimes trees in the same low area in an orchard at Lafayette in which the disease occurred in 1921 and 1923. The first infection was noted July 25. Powdery mildew was reported from Gibson County.

Because of the high rainfall in September, sooty blotch (*Phyllachora pomigena*) was very serious in unsprayed orchards and in commercial orchards where the fungicide was omitted from the later sprays on light varieties such as Grimes.

A shallow surface spotting of Grimes fruit in cold storage, which is caused by an apparently undescribed fungus, has been found by C. E. Baker in the 1924 and 1925 crops grown at Bedford when the fruit was taken out of storage in February or March. The lesions were irregularly circular, slightly sunken, light brown spots, 5 to 15 millimeters in diameter, with an indistinct margin and a silvery area at the center due to the presence of air under the epidermis. Cross-sections showed that about 10 to 12 cell layers under the epidermis were involved, the cells being brown and collapsed. Tissue plantings made both seasons have yielded the same slow-growing fungus characterized by grayish-white, fluffy aerial mycelium at the center of the colony in which are found under the microscope numerous simple hyphal loops or coils of uniform size, and compound hyphal strands. The hyaline, elliptical spores accumulate in small heads or groups on the ends of the short, simple sporophores. In cornmeal agar, this fungus actively dissolves the starch. Successful inoculation was obtained not only through wounds but also by placing fragments of agar colonies upon the unbroken surface of the fruit. In the latter case brown lesions appeared about the lenticels under the agar and from these lesions the fungus was reisolated. Sections of these lesions showed the abundant mycelium freely penetrating the host cells.

Bitter pit was worse than usual in southern Indiana and caused rather heavy losses especially in Stayman and Delicious. Because of the late rains there was also much loss due to growth cracks in the stem cavity in Stayman fruit. A late frost (May 25) caused a peculiar internal necrosis near the calyx end in Grimes and Golden Delicious. The necrotic tissue occupied a rather thin plane parallel to and 1 to 2 mm. under the skin and resulted in marked lop-sidedness of the fruit.

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[7] Schneiderhan, F. J. Apple disease studies in northern Virginia. Va. Agr. Exp. Sta. Bul. 245: 1-35. 1926.

There was a disastrous blossom-drop in the Winesap variety in southern Indiana. On July 25, severe hail injury occurred near Paoli and observation of the behavior of injured fruit in storage later showed that as a rule no rot developed in the hail bruises unless the epidermis was broken.

Bean:—Bacterial blight, caused by *Bacterium phaseoli*, was found to be a serious limiting factor in the rather extensive commercial canning crop in Floyd County in July. The variety grown was Burpee's Stringless Greenpod, and abundant infection occurred on leaves, stems, and pods. Observations in Mains' variety plots at Lafayette showed infection in 45 of the 49 varieties represented.

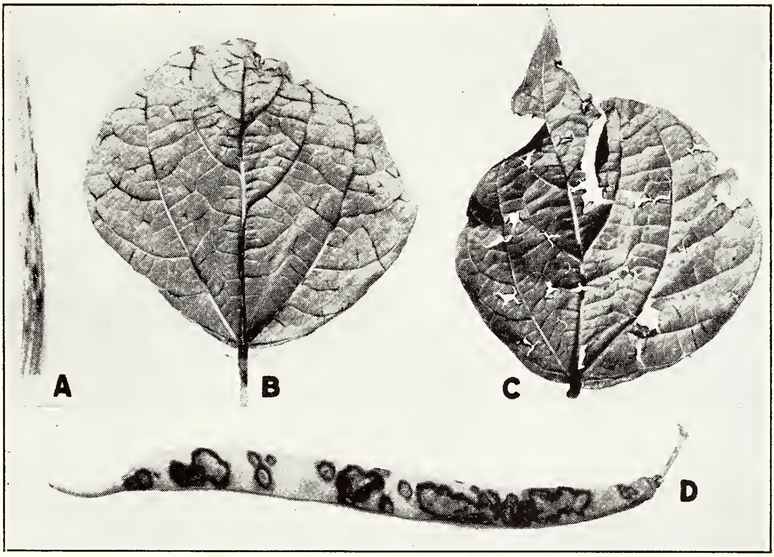

Fig. 2. Bean anthracnose. A.—Stem lesions. B.—Upper surface of leaf showing linear anthracnose lesions along the veins. C.—Leaf torn and shattered about the lesions probably as a result of growth stresses. D.—Pod lesions.

Mosaic occurred in only a small percentage of the commercial crop in Floyd County, but was very destructive in home gardens and occurred in 48 of the varieties in Mains' plots. Anthracnose, caused by *Colletotrichum lindemuthianum*, was found in a field at Lafayette where overhead irrigation was used (fig. 2). Fusarium wilt was noted killing Kentucky Wonder plants in gardens in July.

Beet:—Leaf spot, caused by *Cercospora beticola*, and Rhizoctonia root rot were noted in gardens. Beet seed imported by a beet sugar company was incubated in a damp chamber and on many of the seeds sporophores of a Coprinus developed (fig. 3), a phenomenon previously recorded by Buller.[8]

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[8] Buller, A. H. Reginald. Researches on fungi 3: 308. 1924.

Blackberry:—Leaf spot, caused by *Mycosphaerella rubi,* was noted in Floyd County, and orange rust (*Gymnoconia interstitialis*) in Orange County.

Buckwheat:—Greenhouse inoculation tests with *Ramularia anomala* have been successful on a number of buckwheat varieties and on *Polygonum convolvulus,* but failed on *P. virginianum, P. pennsylvanicum,* and *Rumex sp.* The incubation period was about two weeks. The spores germinated promptly in water mounts.

In field plots a bacterial spot disease of buckwheat was found on August 12. The spots were irregularly circular and 2 to 3 mm. in diameter with a brick-red to madder-red (Ridgway) center and a narrow halo about the margin, yellowish when viewed from above and watersoaked when viewed from below (fig. 4). In microscopic mounts bacteria oozed in abundance from the cut edges of the lesions.

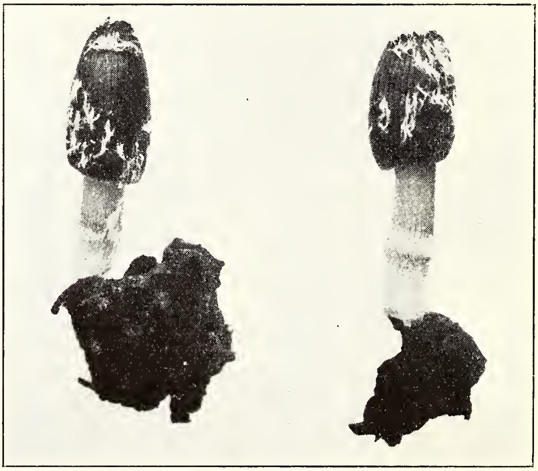

Fig. 3. Coprinus sporophores produced from beet seeds incubated in moist chamber.

Cabbage:—The Fusarium yellows was not as serious as usual, probably because most commercial growers are using resistant strains. Black leg, caused by *Phoma lingam,* was found in Marion County. An Alternaria spot was found on PeTsai cabbage near Indianapolis, in August.

Carrot:—Leaf spot caused by *Cercospora apii carotae* was worse than usual in Indianapolis market gardens.

Celery:—The Fusarium yellows was less severe than usual. The yellows-resistant variety developed by Coons and Nelson in Michigan proved resistant in Indiana. Early blight, caused by *Cercospora apii,* and late blight, caused by *Septoria apii,* were very serious. Gregory reported the latter to be a limiting factor in the crop at Goshen, where spraying with Bordeaux proved very necessary.

Cherry:—Leaf spot, caused by *Coccomyces hiemalis*, was much less prevalent than usual, owing, probably, to the drouth in April and May. Brown rot, caused by *Sclerotinia fruticola*, was worse than usual.

Clover:—Mosaic occurs throughout the state. Mains found it in four strains of red clover and in *Trifolium arvensis*, *T. subterraneum*, *T. incarnatum*, and *T. resupinatum* in his experimental plots. It was most severe in the last two species listed, and was seed-borne in *T. resupinatum*. Powdery mildew was abundant throughout the state late in the summer.

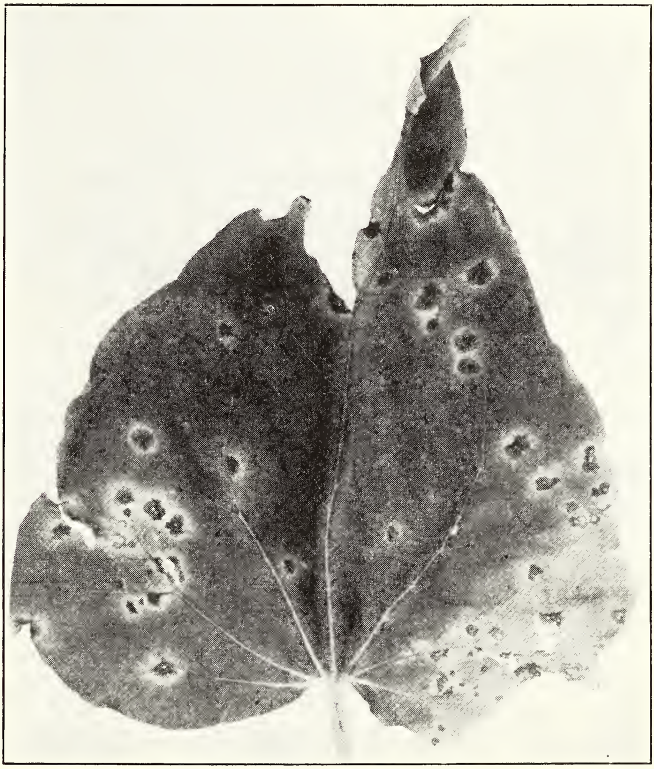

Fig. 4. Bacterial spot of buckwheat.

Bacterial spot, due to *Bact. trifoliorum*, was of common occurrence and was noted by Mains on 29 strains of red clover in his experimental plots. He also noted that alsike clover and one strain of red clover from Finland remained free from infection.

Corn:—Hoffer estimated the losses this year at 3 per cent for Fusarium ear rots, 5 per cent for Gibberella and Fusarium root and stalk rots, and 0.25 per cent for smut (*Ustilago zeae*). Rust (*Puccinia sorghi*) was widespread and bacterial wilt due to *Aplanobacter stewartii* was found in a few fields.

Cowpea:—Cladosporium spot, or scab, caused by *Cladosporium vignae*, was found on the Large Blackeye, Progressive White, and Columbia varieties and on Asparagus bean (*Vigna sesquipedalis*). It is of interest to note that Wingard found this disease on the Blackeye variety in Virginia in 1918 (letter from F. D. Fromme) and that Adams found it on the Clay variety in Delaware in 1921 (letter from J. F. Adams). Bacterial spot due to *Bact. vignae* was found in Knox and Lawrence counties as well as in experimental plots at Lafayette. Leaf spot, due to *Cercospora cruenta*, was noted in the experimental plots.

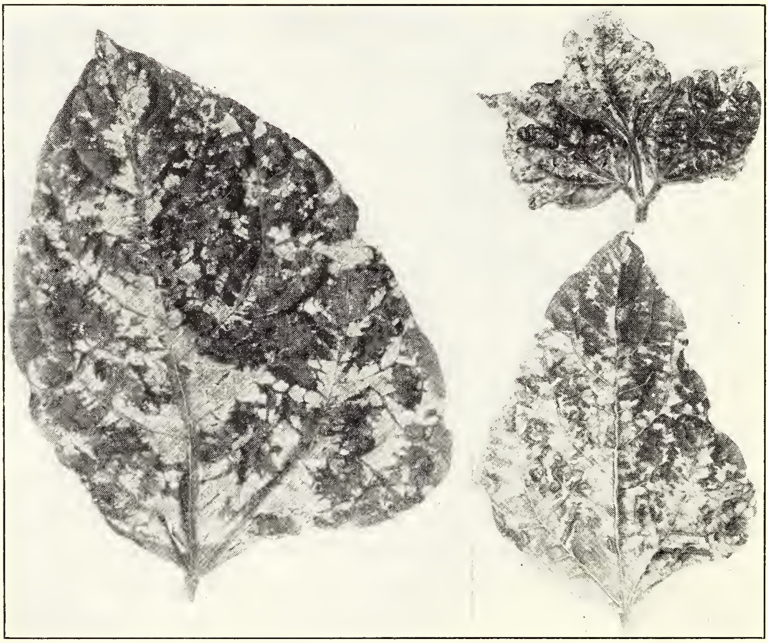

Fig. 5. Cowpea mosaic.

For the first time, mosaic was very prevalent in our experimental plots. Apparently it was introduced with newly acquired seed. It was characterized by a very conspicuous light and dark green pattern on the leaves combined with the puffy areas on the young leaves (fig. 5). Mosaic occurred in 20 varieties of cowpeas and in *Vigna sesquipedalis* and *V. catjang*. The least infection was found in the cowpea varieties, Columbia and Early Buff.

Cucumber:—Bacterial wilt, due to *Bacillus tracheiphilus*, and mosaic were not as severe as usual. Anthracnose (*Colletotrichum lagenarium*) was noted in Floyd County.

Eggplant:—Moisaic was noted on eggplants grown near mosaic tomatoes.

Gooseberry:—Anthracnose (*Pseudopeziza ribis*) was found at Vincennes.

Grape:—Downy mildew (*Plasmopara viticola*) was found rather serious in an Indianapolis market garden in August. Crown gall was sent in from Mooresville.

Horseradish:—Leaf spot, caused by *Cercospora armoraceae*, was found in Floyd County.

Jerusalem artichoke:—A powdery mildew was noted at Lafayette.

Kohlrabi:—Yellows, due to *Fusarium conglutinans*, was found at Vincennes, causing one-sided yellowing of the leaves, defoliation, and stunting. Incubation of specimens proved that the fungus was present in the vascular bundles.

Lima bean:—Bacterial blight, due to *Bact. phaseoli*, and bacterial spot, due to *Bact. vignae*, were noted in Floyd County. Mosaic was observed at Lafayette.

Muskmelon:—Leaf blight, caused by *Macrosporium cucumerinum* (previously attributed to *A. brassicae nigrescens*), was the most serious disease of the crop in southern Indiana. The leaves were killed prematurely, many melons failed to ripen, and such as did mature were poor in quality. Bacterial wilt and mosaic were not as severe as usual.

Onion:—Botrytis rot occurred rather commonly in storage, as did also bacterial soft rot. Much of the Botrytis infection, which on the yellow onions showed up in storage as a large circular black spot on the side of the bulb, apparently followed freezing injury to the outer scale.

Owing to the high winds in the Kankakee Valley in the spring which blew out the recently planted seed and drifted the muck soil like snow, many fields had to be replanted and hence the crop did not mature before the cool, wet weather of fall. The freeze in October seriously injured the crop in some sections. Inspection of such a crop in a Jasper County storage house in the late fall showed that there was much loss due to fungous discoloration of the outer scales. There was much black mold (*Aspergillus niger*), blotch (*Macrosporium sp.*), and "silver spot" (*Penicillium sp.*) on both yellow and red varieties. The blotch is characterized by numerous narrow, black, longitudinal rifts in a greenish area. The silver spot takes the form of a row of small, circular, silver patches along a vein, and on each of these a Penicillium species sporulated when specimens were incubated in a moist chamber.

Parsnip:—The leaf spot due to *Cercospora pastinacae* was very prevalent. This fungus was erroneously designated as a Cercosporella in the 1921 and 1922 reports. A trouble closely resembling a mosaic disease was noted in August.

Peach:—Bacterial spot, due to *Bact. pruni*, was much less prevalent than usual, in fact did not become at all abundant until late in the summer. Scab, caused by *Cladosporium carpophilum*, was noted on Krummel fruit in the fall and cankers were abundant on the 1924 twigs in many orchards. Leaf curl, caused by *Exoascus deformans*, was serious only in unsprayed trees.

Brown rot, due to *Sclerotinia fruticola,* was found prevalent on the fruit of unsprayed Champion trees in Orange County in July. In a commercial orchard of the Krummel variety in Knox County, this disease caused a loss in September estimated by the owner at 1,500 bushels or $4,500. This orchard had been well sprayed and most of the brown rot infection occurred in the abundant growth cracks which were the result, presumably, of a late fertilizer application and of the high rainfall in September. These cracks constituted open wounds of such recent origin that the sprays afforded no protection. There was evidence of twig infection as a result of the fungus growing up through the peduncle of the rotted fruits.

According to Pierce, another very important contributing factor in this brown rot attack was the presence, scattered through this orchard, of a number of seedling trees. These trees are usually not well sprayed and their worthless fruit, which in this case matured well in advance of the commercial variety, were rotted by the brown rot fungus, and afforded a reservoir of infection for the later-maturing commercial crop. Worthless seedling trees occur very commonly in commercial orchards and constitute a dangerous and entirely unnecessary brown rot hazard.

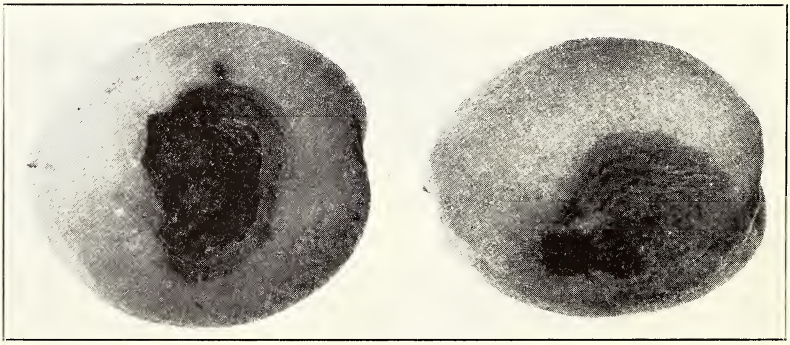

Fig. 6. Rot of peaches caused by the apple black rot fungus. Infection followed hail injury.

In a commercial orchard of the Early Elberta variety in Lawrence County, severe hail injury to the fruit occurred late in July and on August 4 it was found that about 5 per cent of the wounded fruits were affected with a firm, dry, sunken rot in which the tissue involved was tough and black (fig. 6). Pycnidia and spores resembling those of *Sphaeropsis malorum* were found on some of the lesions. Tissue plantings from the advancing face of the rot lesion yielded a fungus which, when inoculated into apples, produced a typical black rot with pycnidia and spores of *Sphaeropsis malorum.* Thus it appears that the hail-injured peaches were attacked by the apple black-rot fungus.

There was some Rhizopus rot of the fruit in the orchard of the Krummel variety mentioned above. In early spring spray tests it was found that weak Bordeaux caused shot hole lesions in the leaves, yellowing, and premature defoliation.

Pear:—Fire blight, due to *Bacillus amylovorus,* was very destructive in the spring. Leaf spot, due to *Mycosphaerella sentina,* was abundant on unsprayed trees.

Pepper:—Mosaic was prevalent in market gardens.

Plum:—Brown rot, due to *Sclerotinia fruticola,* and black knot, due to *Plowrightia morbosa,* were common on door-yard trees.

Potato:—The situation with respect to leaf roll and mosaic remains as stated for 1924[9]. Blackleg, caused by *Bacillus phytophthorus,* was the cause of rather serious losses in the early crop (Cobblers and Ohios) in certain fields in southern Indiana. Gregory found that most of this infection occurred in fields planted from the same trainload of Minnesota seed tubers. Fusarium wilt was noted in the Cobbler and Bliss varieties in June. Scab, caused by *Actinomyces scabies,* and black scurf (*Rhizoctonia solani*) were rather prevalent.

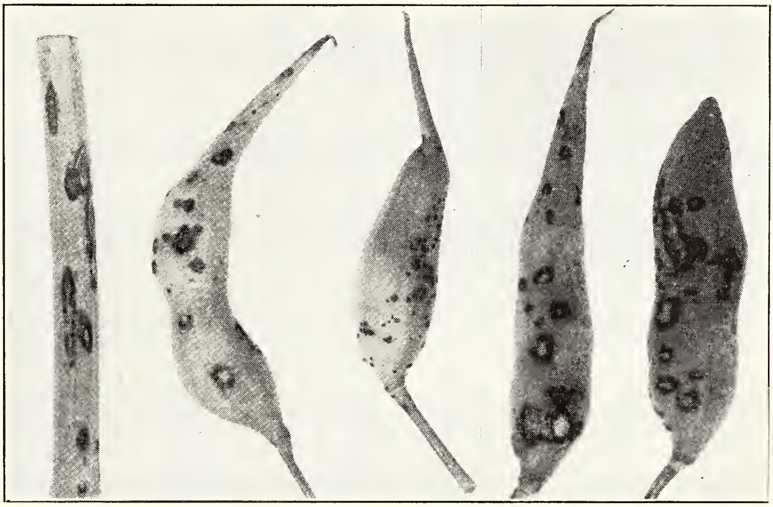

Fig. 7. Radish stem and pods showing lesions with which an Alternaria was associated.

Quince:—Fire blight, due to *Bacillus amylovorus,* occurred in La-Porte County.

Radish:—Black root, due to *Aphanomyces raphani* Kendrick,[10] was serious in gardens in Lafayette. Downy mildew (*Peronospora parasitica*) was found on seed pods in August and white rust (*Cystopus candidus*) was noted on the leaves in the fall. Small black lesions were noted on the leaves, peduncles, and seed pods, with which an Alternaria was associated (fig. 7). An unmistakable mosaic occurred in October on a number of varieties in an experimental plot at Lafayette. The mottling and puffy, dark green areas on the leaves were typical mosaic symptoms, and in addition there was some necrosis along the veins.

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[9] Gardner, Max W. Potato and tomato diseases. Trans. Ind. Hort. Soc. 1924: 124-132. 1925.

[10] Kendrick, James B. Radish black-root caused by *Aphanomyces raphani* n. sp. Abs. in Phytopath. 17:43. 1927.

Raspberry:—Anthracnose (*Plectodiscella veneta*) is the limiting factor in commercial black cap plantings. Dietz reports that the delayed dormant spray is being used in nurseries with good results, an important step towards checking the disease at its source. Crown gall at the nodes along the canes was found on black raspberries at Elkhart. Powdery mildew was noted on the leaves of red raspberries at Lafayette. Leaf curl is very destructive in the black varieties.

Soybean:—Bacterial blight, caused by *Bact. glycineum*, was of general occurrence. Mosaic was observed in the Midwest variety in Floyd and Lawrence counties and occurred in a number of varieties in experimental plots at Lafayette. Leaf drop accompanied by necrotic symptoms in the shape of streaks along the leaf veins, blotches on the stem, and blighting of the growing tip occurred only in the Lexington variety. Dunfield, a variety commonly grown and one increasing in popularity in Indiana, seems to be rather resistant to mosaic.

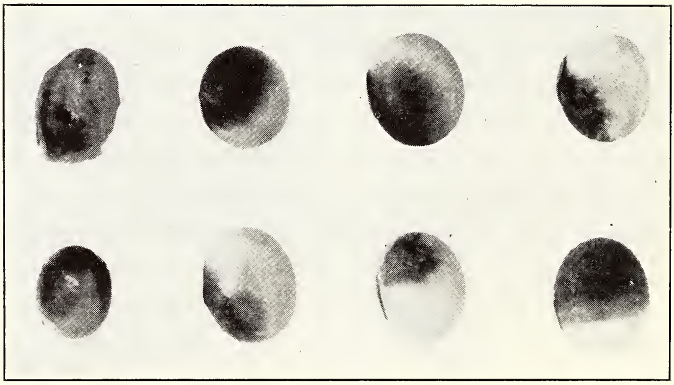

Fig. 8. Purple seed stain of soybean caused by a species of Cercospora. (Enlarged).

The purple seed stain noted in 1924 occurred again this year in various parts of the state and was very objectionable to growers who desired seed certification (fig. 8). This trouble has been found to be due to the presence of the mycelium of a Cercospora between the layers of the seed coat. The fungus has been cultured from surface-sterilized, discolored seeds and likewise from cotyledons invaded, it is thought, during the process of germination. It seems very likely that this disease is identical with the purple speck[11] disease reported in Japan and caused by *Cercospora kikuchii.*

Strawberry:—Leaf spot caused by *Mycosphaerella fragariae* was coexistent with the crop, and leaf blotch caused by *Mollisia earliana* was found in Floyd County.

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[11] Matsumoto, T. and Tomoyasu, R. Studies on purple speck of soybean seed. Ann. Phytopath. Soc. Japan 1 (6): 1-14. 1925.

Sweet potato:—Fusarium stem rot (or yellows), scurf, caused by *Monilochaetes infuscans,* and black rot, caused by *Ceratostomella fimbriata,* were noted in Knox County. An early freeze in the fall injured the keeping qualities of the roots not yet harvested.

Tobacco:—Blackfire, due to *Bact. angulatum,* and mosaic were found in Floyd County.

Tomato:—As in 1924, the worst disease during the 1925 season was leaf-spot, due to *Septoria lycopersici,* probably because of the frequent rains during the latter part of the season. Furthermore, the low temperatures of July and August retarded the crop so that the effects of the disease were more serious. During the hot weather of September there was much sun scald injury of the exposed fruits on the plants defoliated by leaf-spot.

In the opinion of many growers, early blight, caused by *Alternaria solani,* was more destructive than Septoria leaf spot. Certainly it became serious much earlier and was equally as prevalent. In fact early blight was more prevalent than had been noted during the preceding six years. It was especially bad in Hancock, Orange, and Morgan counties in early August. Specimens from Morgan County showed abundant and conspicuous lesions on stems, petioles, leaves, peduncles, calyces, and young green fruits. Calyx lobes were killed and on these were found numerous spores of the fungus. On the young fruits were numerous, very small, black, circular, raised spots. Larger lesions were commonly found later in the season, especially about the stem end, and so situated as to suggest that they had resulted from calyx infection. In one case the mycelium was found penetrating through the pericarp and into the neighborhood of the seeds. In fact the mycelium was found among the hairs on the surface of the seeds, an excellent arrangement, it would seem, for seed carriage of the fungus.

In central Indiana, Fusarium wilt was not very destructive this year, probably because of the low temperatures of July and August. The hot weather in June was favorable to the disease and it assumed serious proportions in southern Indiana, especially in Gibson County.

Mosaic was widespread in the field crop and the more serious double-virus or streak type was common in greenhouses. As Vanterpool[12] has shown, the streak type of mosaic is due to the presence of two viruses, that of typical tomato mosaic and a virus from potatoes. Our observations and tests indicate that only one of these viruses, viz., that of typical tomato mosaic, is carried in the perennial weeds such as Physalis, and that the other virus involved may frequently be found in apparently healthy as well as in mosaic potato plants. Thus, potatoes constitute a distinct disease menace to tomatoes. Greenhouse growers especially should guard against the possible infection of their tomato crop by the potato virus from volunteer plants or sprouted tubers and from insects that might have come from potato fields. Potatoes should not be stored in rooms or pits connecting with greenhouses, nor should potato tubers be used as poisoned bait for sow bugs in greenhouses used for tomatoes.

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[12] Vanterpool, T. C. Streak or winter blight of tomato in Quebec. Phytopath. 16: 311-331. 1926.

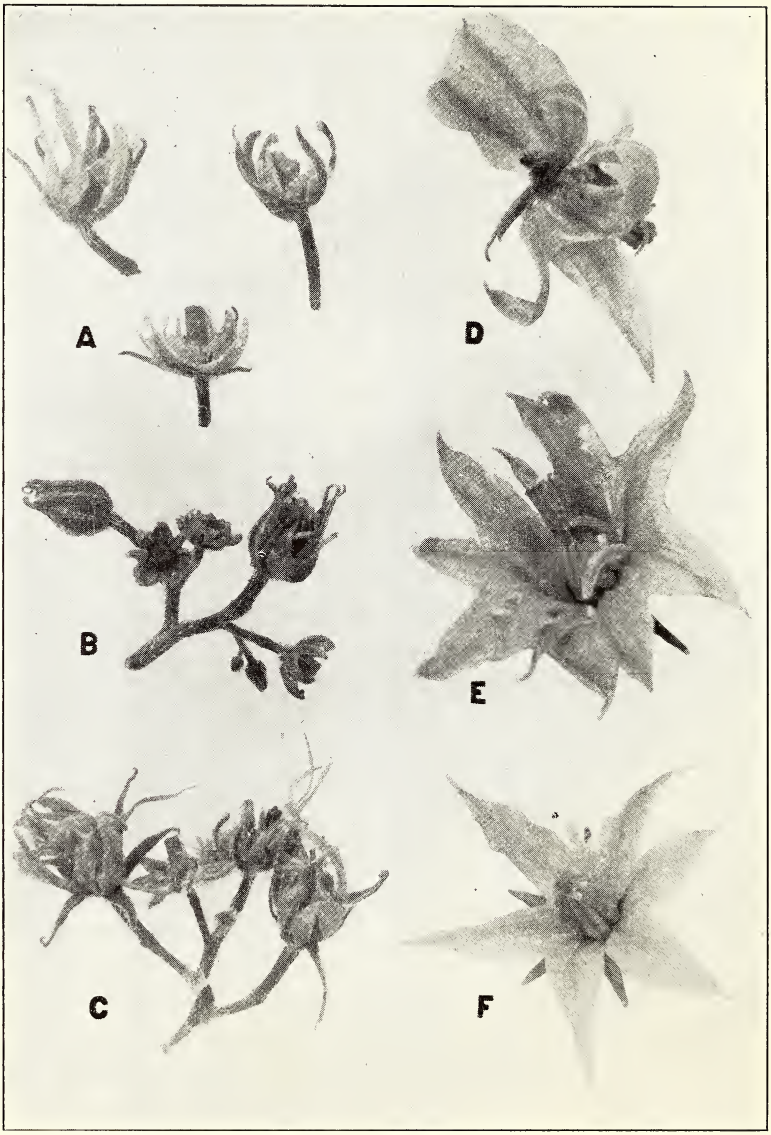

Fig. 9. Effect of fern leaf mosaic on tomato blossoms. A, B, C.—Blossoms opened prematurely and abnormally; corolla lobes long and twisted; styles enlarged. D.—Dorsal view of flower showing extremely irregular corolla and much reduced calyx. E.—Flower showing accessory corolla whorl. F.—Normal flower.

A study of the effects of the filiform or fern-leaf type of mosaic on the floral anatomy showed that the calyx lobes were sometimes strap-shaped, sometimes two-lobed, sometimes reduced in number to as low as two (fig. 9). The corolla lobes might be of unequal length or size and might be increased in number, and the corolla tube might be longer than normal or divided clear to the base with the lobes linear or strap-shaped. In some cases there was on accessory whorl in the corolla. The flowers were sometimes irregular and showed a tendency to open prematurely before the corolla was developed. There was a tendency toward incomplete union in the compound style with prominent ridges corresponding to its component parts and sometimes with the stigmatic surfaces at different levels. Sometimes there were two ovaries in the flower, and frequently stamen filaments and corolla lobes were found caught and held fast between the folds of the ovary wall. The extreme reduction of the leaves is illustrated in figure 10. Where the leaflets were reduced to mere midribs there was often a tendency for the latter to be twisted.

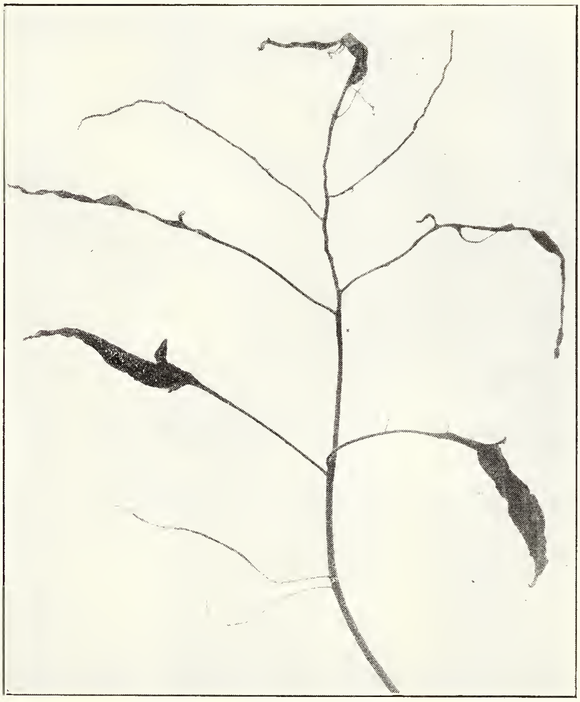

Fig. 10. Effect of fernleaf mosaic on tomato leaf. Leaflets reduced almost to bare midribs, some of which are twisted.

Leaf mold (*Cladosporium fulvum*) was serious in greenhouses. Fruit invasion was observed. Bacterial spot, caused by *Bact. vesicatorium*, was worse than usual and was found in the group of counties consisting of Hancock, Henry, Madison, Tipton, and Howard. Anthracnose (*Gloeosporium phomoides*) was worse than usual, owing to the heavy rainfall in September, and proved very objectionable to canners because, being rather inconspicuous, it was easily overlooked on the sorting belt and hence increased the mold count in the pulp. Rhizoctonia soil rot was serious in the canning crop in Madison County, producing a brown, concentrically ringed lesion at the point where the fruit touched the soil. This lesion usually cracks radially and the tough, brown, rotted tissue is known among the canners as core rot. The frosty white hymenium is often produced on the surface of the fruit and extends out over the sound tissue far beyond the periphery of the lesion. Buckeye rot, due to *Phytophthora terrestris*, was found in Indianapolis market gardens in August and was destructive in certain greenhouses.

In the canning crop, blossom-end rot and growth cracks were not serious this year, but sun scald and fungous rots were worse than usual. Early in July a number of cases of lightning injury were observed in fields in Tipton County.

Turnip:—A very destructive outbreak of mosaic following an aphis infestation occurred in an experimental plot at Lafayette. The affected plants were greatly stunted and the roots practically worthless.

Velvet bean:—Bacterial spot, due to *Bact. vignae*, and mosaic occurred in experimental plots.

Watermelon:—Anthracnose (*Colletotrichum lagenarium*) was much worse than usual and was found killing the vines in Lawrence County late in July. Fusarium wilt was reported from Jefferson County. One plant showing mosaic symptoms was found.

Miscellaneous:—Aster yellows, which Kunkel has found to be transmitted only by a certain leaf-hopper and to have a wide host range, was not at all common as compared with last year. The Fusarium wilt was more prevalent, however.

A peculiar disease of Delphiniums consisting of a thickening and malformation of the leaves and failure to blossom properly proved very troublesome and is suspected to be a virus disease.

Geranium bacterial spot, caused by *Bact. erodii*, was noted, and an unmistakable mosaic disease was found by Gregory.

Dietz found the bacterial disease of gladiolus, due to *Bact. marginatum*, rather widespread in the state, and Drayton of the Canada Department of Agriculture found hard rot caused by *Seporia gladioli* and a Sclerotium dry rot in corms from northern Indiana.

Iris leaf spot due to *Didymellina iridis* and a Sclerotium rot were serious at Lafayette.

A thread blight of a small black oak sapling was found at Lafayette in October. The fungus appeared to be a Rhizoctonia. The whitish or tan mycelium grew from the soil up along the stem, out along the petioles, and spread in a mat over the lower surface of the basal third of each leaf blade, killing the leaf blade tissues.

Snapdragon rust (*Puccinia antirrhini*) was destructive in greenhouses and gardens. A very slight infection of sycamore anthracnose was noted. Unmistakable mosaic diseases were noted on *Helianthus strumosus* and *Anchusa officinalis*. *Phyllachora graminis* was observed on *Hystrix hystrix* and *Elymus virginicus*. A Cercospora leaf spot was found on Ampelopsis and *Entyloma australe* was found on *Physalis subglabrata*.

SUMMARY.

The diseases of outstanding importance this season were apple fire blight and bitter rot, cantaloupe leaf blight, celery late blight, peach brown rot, potato black leg, tomato Septoria leaf spot and early blight, and watermelon anthracnose.

The diseases or parasitic organisms not previously reported for the state, at least in this series, include: bacterial root rot of alfalfa, surface rot of apple, bacterial spot of buckwheat, geranium mosaic, Sclerotium dry rot of gladiolus, kohl rabi yellows (*Fusarium conglutinans*), Rhizoctonia thread blight of black oak, onion blotch (Macrosporium) and silver spot (Penicillium), radish mosaic and Alternaria spot, and raspberry powdery mildew.

THE SEEDING HABITS OF WHITE SNAKEROOT, EUPATORIUM URTICAEFOLIUM REICHARD.[1]

ALBERT A. HANSEN, Purdue University Agricultural Experiment Station.

On account of the economic importance of white snakeroot, *Eupatorium urticaefolium* Reichard, as a poisonous species in Indiana, the destruction of the plant is a live question among farmers. The only practical method of eradication, aside from clearing the infested woods and cultivating the land, is hand pulling during September when the bright flowers are conspicuous and preferably following rain when the ground is soft and the roots yield readily. Mowing is of little avail since the perennial roots sprout readily.

In connection with this method of eradication, a knowledge of the seeding habits of the plant is of importance. To obtain this knowledge, 200 mature seeds were gathered in White County on October 1, 1923, and submitted to the Seed Laboratory at Purdue University. A germination test of 28 days' duration, starting on October 5, 1923, failed to germinate a single seed. On November 1, 1924, another lot of mature seed was gathered near Lafayette, and attempts to germinate them on moist blotting paper were equally unsuccessful.

On August 15, 1924, a single specimen of white snakeroot in full flower was transplanted from a woodlot near Lafayette to a shady situation under a large ninebark, *Opulaster opulifolius* (L.) Kuntze, located on the Purdue University campus where no white snakeroot was present or has ever been known to grow. The plant ripened seed in a normal manner. The following summer numerous seedlings appeared, although no attempt was made to count them. Several of these plants in turn formed seeds. On October 22, 1926, the snakeroot plants were counted and it was found that in two years the single plant had developed 81 progeny, in spite of the fact that the shade under the ninebark was so deep that only a few of the snakeroot plants actually formed seeds. The plants were all true seedlings since white snakeroot has no means of vegetative reproduction aside from the branches that grow directly from the center of the perennial root cluster.

This simple experiment proved that white snakeroot can reproduce freely from seed when allowed to grow under natural conditions. The production of numerous seedlings of white snakeroot was also noted in the garden of Prof. H. S. Jackson at West Lafayette. The practical importance of this information is obvious in the eradication of white snakeroot. Since the plants go to seed, it is necessary to remove them from the woods after hand pulling rather than merely to shatter the soil from the roots and then cast the plants aside to die. When the latter is done, the pulled plants readily go to seed. Complete

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[1] Contribution from the Botanical Department of the Purdue University Agricultural Experiment Station.

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eradication should also be practiced, otherwise the remaining plants will go to seed and reinfest the area. Furthermore, on account of the seeding habit, the hand pulling during early September should be repeated several years in order to destroy the plants that originate from seeds that have remained dormant in the soil for two or more years.

RECENT INDIANA WEEDS, 1926[1]

ALBERT A. HANSEN, Purdue University Agricultural Experiment Station.

The present paper is a continuation of a series of contributions, started in 1922, which attempts to record the occurrence in Indiana of plants new to the state, particularly species with weedy habits. Established plants that have recently exhibited troublesome tendencies are also considered. The growing season of 1926 is the basis of the following record. In each case, the identification was verified by the United States Department of Agriculture, the New York Botanical Garden, or the Gray Herbarium of Harvard University. Specimens have been deposited in the herbarium of Purdue University Agricultural Experiment Station.

Field Peppergrass.—*Lepidium campestre* (L.) R. Br. Although not included in Coulter's catalogue of Indiana plants, this species is at present so widespread that it probably occurs in every county in the state and has recently taken rank as one of the worst weeds of meadows, pastures and grain crops. The wide distribution of the plant is probably due to the use of impure clover, timothy and alfalfa seed. Field peppergrass is an exceedingly troublesome and persistent plant that is difficult to eradicate under Indiana conditions.

Creeping Yellow Water Cress.—*Radicula sylvestris* (L.) Druce. A native of Eurasia with perennial roots and creeping stems from which new plants arise in abundance. Specimens in full flower were collected in a pasture field and along fencerows near Elwood. Palmer J. Davis, vocational instructor at Elwood High School, states that the plant is causing some alarm among farmers in the vicinity due to its persistence and the habit of reproducing from the creeping stems. Prefers moist ground. The identification was confirmed by S. F. Blake of the U. S. Department of Agriculture.

Squaw-weed.—*Senecio obovatus* Muhl. Found in Montgomery County, notably on the J. F. Dice farm, R. 1, Crawfordsville. Mr. Dice states that the species has recently appeared in his locality and it spreads rapidly, the young plants forming a solid mat on the ground. On the Dice farm a hillside in bluegrass pasture is thoroughly infested with the squaw-weed. The identification was verified by Percy Wilson of the New York Botanical Garden.

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[1] Contribution from the Department of Botany, Purdue University Agricultural Experiment Station.

Little Barley.—*Hordeum pusillum* Nutt. This species, although not recorded in Coulter's Catalogue of Indiana plants, is becoming exceedingly abundant in southwestern Indiana, particularly in Vanderburgh Posey, Warrick and Gibson counties. The identification of a specimen collected in dry soil along a roadside near Evansville in Vanderburgh County was verified by B. L. Robinson of the Gray Herbarium. Little barley occasionally becomes a troublesome weed in alfalfa fields.

Dove's foot Crane's-bill.—*Geranium molle* L. Established along roadside near Battle Ground, where specimens in full flower were collected on May 26, 1926. Identification confirmed by J. K. Small, New York Botanical Garden.

Red Orache.—*Atriplex rosea* L. Although widely distributed over the United States, no previous report of its occurrence in Indiana can be found. A common weed in Porter County where on the S. C. Hardesty farm near Hobart it is a serious pest, particularly in alfalfa, and is spreading rapidly. It was probably introduced by means of impure alfalfa seed. Identification confirmed by Ivan M. Johnston of the Gray Herbarium.

Halberd-leaved Orache.—*Atriplex hastata* L. A common species in the vicinity of Lafayette. Thrives in vacant lots, along roadsides and in waste places generally. It has also been observed in Lake and Porter counties, where no specimens were collected.

Miscellaneous.—Millet, *Panicum miliaceum* L., cultivated in Europe as a food plant and to some extent in America for forage, is established in Fulton County where it grows in fields and along fencerows. The identification was confirmed by P. L. Ricker of the U. S. Department of Agriculture.

A giant form of *Setaria viridis* (L.) Beauv. was found growing freely in fields in Hancock County. The plant was at first thought to be the cultivated foxtail millet, *S. italica* Beauv., but A. S. Hitchcock referred the species to *S. viridis.* He states that he has found the same large form growing in China.

Burweed Marsh Elder, *Iva xanthiifolia* Nutt., grows along ditch banks in Tippecanoe County. A specimen in early flower was collected on July 19, 1926.

Spotted Knapweed, *Centaurea maculosa* Lam., occurs as a weed near Atlanta.

A patch of hoary cress, *Lepidium draba* L., which is about an acre in extent and which has persisted for several years, occurs on the Grant Thomas farm near Milroy.

Near Anderson there is an infestation of a plant that appears to be a wild form of the common garden lettuce, *Lactuca sativa* L. On one farm where the plant infests about five acres of land and is very thick in places, the farmer considers it a bad weed.

A BOTRYTIS DISEASE OF RIBES ODORATA WENDL.

J. M. Van Hook, Indiana University.

This is a disease of both leaves and shoots of *Ribes ordorata* Wendl., commonly known as golden currant or clove bush and is caused by a Botrytis species, most probably a strain of *B. cinerea* Pers. It was first discovered in a large cluster of these bushes eight years ago, and has been under observation each year since. The exact location is six miles west of Bloomington, Indiana. This clump of bushes is very large, having spread to some 20 feet in diameter and some of the canes reach to a height of six feet.

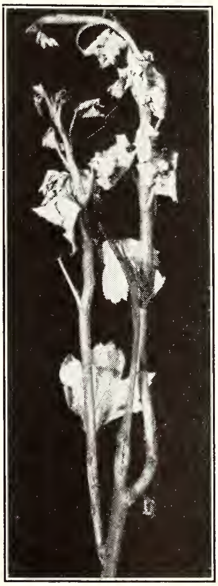

Fig. 1. "Die back" of golden currant produced by inoculation with Botrytis. Two lateral shoots have rapidly developed. These are larger than the main stem. (Much reduced.)

The most striking effect of the disease is the injury done to the young growing shoots. These are killed back, usually about six inches, the tips curling downward as they dry up. Figure 1 shows the characteristic appearance of such twigs. Conidiophores of the causal fungus may be seen surrounding and growing from these dead stems, especially near their tips. The infection appears to begin at the very tip of some terminal or lateral shoot. As it proceeds downward, the very young side branches also die and curl. Eventually, when its progress is

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halted by the older and more woody tissue farther down, the buds or side shoots below take the lead and develop very rapidly both in length and in diameter. Many of these newly formed lateral branches are much larger in diameter above than at the base. Usually several of these branches appear, giving a "witches' broom" effect. Occasionally these newly formed branches are, in turn, attacked at their tips and die back as did the original stem. Again, these side branches may die on account of the main stem having died down below their point of attachment.

On the leaves, wedge-shaped spots are usually formed, due to the death of some vein. The attack of veins is a thing naturally expected of a shoot-destroying organism. The start is sometimes back from the edge of the leaf, in which case an oval or circular spot is formed. This may spread gradually over a large area of the leaf. Conidiophores of the fungus always appear on the under surface of such leaves. These spots have purplish margins with brown centers which dry and fade to gray. Much defoliation occurs during seasons favorable to the fungus.

A few vigorous tips of canes in a clump of the same species of *Ribes* as the one upon which the *Botrytis* was found, were selected for inoculation. This clump of bushes has been growing on the Indiana University campus for some 20 years and is known never to have suffered from this disease. Spores in water merely placed upon these tender growing tips on July 6, 1924, produced by July 18—12 days later—the specimen from which the figure was made. The two large axillary shoots were thus very rapidly produced. However, it is interesting to note that the disease has not appeared in this clump since.

While no critical study of the causal Botrytis has been made, it seems, at least, to be a strain of *B. cinerea* Pers. This species is one of some 200. A number are known to be parasites whose virulence depends largely upon their ability to form extraordinarily vigorous mycelia and to attack their hosts at the most favorable time. The literature on *B. cinerea* Pers. is very voluminous and the writer will not discuss it here. Some of the hosts mentioned, however, are: strawberry, dahlia, geranium, lily, carrot, cranberry, fig, ginseng, syringa, peony, cyclamen, lettuce, grape, rose, bean, Prunus, horse-chestnut, and conifers including hemlock, pine, spruce, larch, and fir. Very recently a spur blight of pear in Oregon is noted by Zeller as being caused by *B. cinerea* Pers.

So far as the author is able to learn, this is the first time *B. cinerea* Pers. has been reported on *Ribes odorata* Wendl. It has, however been described on gooseberry, a near relative of golden currant by Salmon[1] in England in 1909, who states that the sclerotia produce both conidia and ascospores. In 1910 Salmon[2] gives to the fungus the name of Sclerotinia. He states that the stem and bases of the branches, the young wood, leaves, and wood are attacked.

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[1] Salmon, E. S. The Sclerotinia (Botrytis) disease of gooseberry, or die back. Jour. Southeast. Agr. Col. Wye, 1909: 319-327.

[2] Salmon, E. S. Sclerotinia or die back of the gooseberry. Jour. Bd. Agr. 17; 1-9. 1910.

In the United States, the "die back" of gooseberry due to a Botrytis seems to have been first noted by Jackson[3] in Oregon in 1915. He states that it is common in Oregon. Heald and Dana[4] in 1924 state that "the terminal and leaf clusters of the current year's growth were killed back". In 1920, Warmald[5] in writing of the disease in England, gives *B. cinerea* Pers. as the cause of die back and says the ascigerous stage is *Sclerotinia Fuckeliana* De By. Though we are not absolutely sure that the die back of gooseberries and the die back of golden currant described herein are identical, we feel reasonably certain of it. Future inoculation experiments will determine definitely the truth.

While we will not here discuss the parasitism or the species limitations of this fungus, it seems well to state that the location of the infected bushes is in a small, but not deep valley, where the air drainage is not of the best and that the plants receive considerable shade. Not a single summer has passed without the recurrence of the disease since its discovery, though there is much difference in its severity from year to year. In general, it is of less importance in seasons of dry summers, especially if such summers are preceded by dry spring seasons as in 1925 and in 1926. During the season just passed, it was less noticeable than in any season since 1918. This year, it first appeared about June 10. It was noted several times in July, but on only a few stems and leaves. During certain seasons, almost every stem and branch die back. It usually reaches the height of its severity in July.

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[3] Jackson, H. S. Notes, observations and minor investigations on plant diseases. Oreg. Biennial Crop Pest and Hort. Rep. 1913-1914: 261-283. 1915.

[4] Heald, F. D., and Dana, B. F. Notes on plant disease in Washington. Botrytis diseases. Trans. Am. Mic. Soc. **43**: 136-144. 1924.

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AMORPHOPHALUS TITANUM.

T. G. YUNCKER, DePauw University.

At the Royal Botanical Gardens, Kew, England, this past summer the writer had the rare opportunity of witnessing the blossoming of that most remarkable aroid, *Amorphophalus titanum*, and of taking some pictures of it. It is believed that a brief description of this unusual plant may be of interest to the members of the Academy.

This plant, a member of the family Araceae, is a native of Sumatra and one of the wonders of the vegetable world. The specific name, *titanum*, is quite properly applied because it is one of the largest, if not the largest, member of its family. Members of this family well known in this part of the world are the Jack-in-the-Pulpit or Indian Turnip, Dragon Flower, Sweet Flag and Skunk Cabbage, all comparatively small plants.

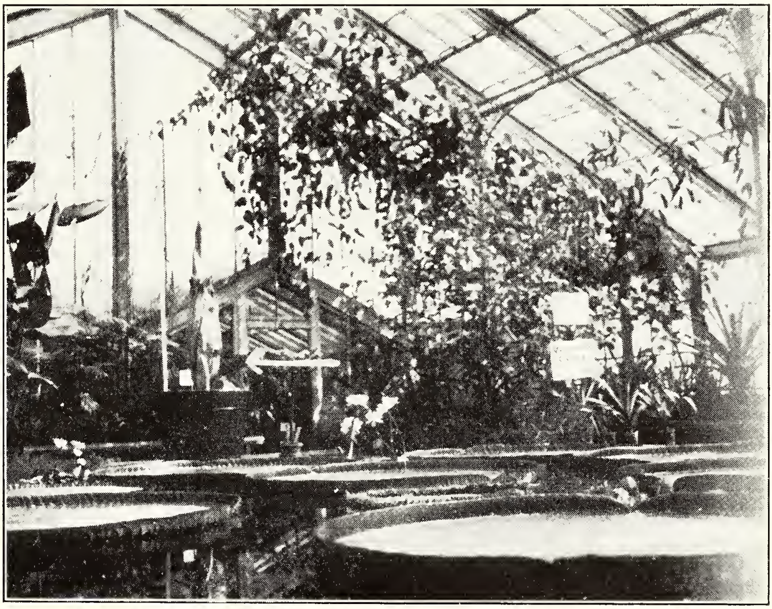

Fig. 1. The "flower" of *Amorphophalus titanum* about half developed showing the spathe folded about the projecting spadix. The giant leaves of *Victoria regia* are to be seen in the foreground.

This species is not easily cultivated out of its native habitat. The first plant to bloom under cultivation, as far as I can discover was one

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grown from seed in the Royal Botanical Gardens at Kew which flowered in 1889. Rarely has it been grown since. The present plant, I believe, is only the second or third to bloom at Kew.

It develops a tuber which has been known to reach a circumference of six and a half feet and to weigh over 50 pounds. The specimen seen this summer was developed from a tuber obtained from Sumatra in August of 1924. Last year (1925) it developed a leaf only.

The leaf is compound, becoming 15 to 20 feet high, and with the blade often having a circumference of 40 to 50 feet. One of the attendants explained that the leaf in 1925 reached the top of the house. This plant was developed in a large tub kept in the *Victoria regia* house at a comparatively high temperature.

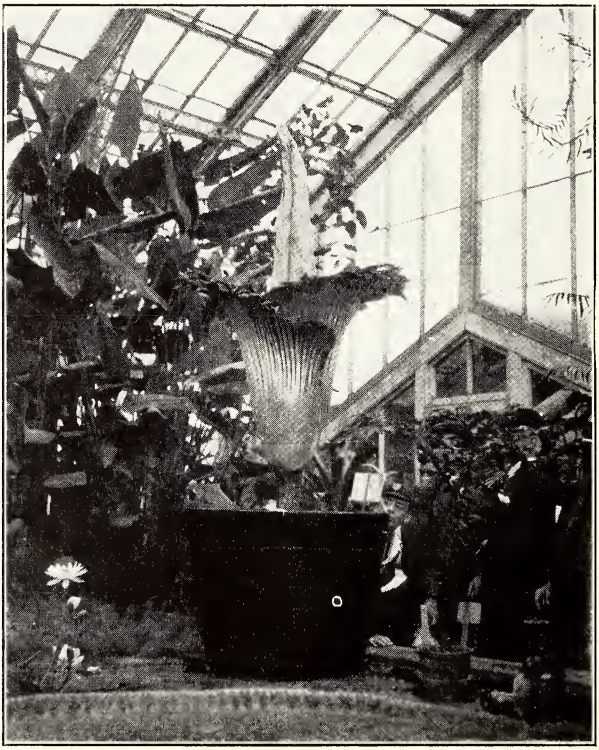

Fig. 2. A fully opened "flower."

In its flowering habit it much resembles that of a gigantic calla lily. It forms a large central column or spadix about ten inches thick which tapers toward the apex. About the spadix is an enveloping, inverted, bell-shaped sheath or spathe which when fully expanded was about three feet long and four feet across. The spathe is furrowed toward the top and irregular at the outer edge. Before blossoming the spathe is closely folded about the protruding spadix. Elongation of the whole is very rapid until the spathe unfolds. Measurements were taken of the plant from day to day and the rapidity of the development is indicated in the following table:

	Height			Height	
Date	Feet	Inches	Date	Feet	Inches
July 23	2	11½	July 30	5	1½
July 24	3	3½	July 31	5	3½
July 25	3	7	Aug. 2	5	6
July 26	3	11½	Aug. 2	5	7
July 27	4	2½	Aug. 3	5	8
July 28	4	6	Aug. 4	5	9
July 29	4	9½	Aug. 5	Fully opened-elongation ceased.	

The spathe was purplish on the inner flare and green on the outside. The spadix was a yellowish tan in color and irregular in outline, becoming furrowed or wrinkled as the "flower" aged. The flowers proper are produced on the basal portion of the spadix as with our common Indian Turnip, but it was impossible to examine them without injuring the spathe.

Commonly the spathe remains open only a few hours before withering. However, the specimen observed this summer remained in good condition for about two days and then a hoop placed about the spathe supported it in normal position for nearly a week before it completely wilted. When first opened the "flower" emitted a vile odor readily distinguishable throughout the house, but after the first day this odor was not noticeable.

The London papers carried articles and pictures featuring the plant and a great many persons came to the Gardens to see it. Especially was this true on Sunday when a line of visitors formed outside of the house waiting turn to enter and examine this very unusual and rare specimen of plant growth.

ADDITIONS TO A BIBLIOGRAPHY OF THE GENUS CUSCUTA.

T. G. Yuncker, DePauw University.

In 1920, in connection with a paper on the North American and West Indian species of Cuscuta, the writer presented a bibliography of 287 titles of papers dealing with the genus Cuscuta. Since the appearance of this list a number of articles have appeared treating of this group. Some earlier ones, also, have been discovered which were overlooked in the former list. It is with the idea of bringing the bibliography up to date that the following list is presented. In a few cases the original articles have not been seen by the writer and the citations thus positively verified.

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SURVEY OF THE VEGETATION IN THE VICINITY OF CEMENT MILLS.

C. L. Porter, Purdue University.

Modern industry has contributed much to agriculture. On the other hand, it has been responsible for many new problems in agriculture. Pioneer farming was attempted for the most part on virgin soil supplied with all of the nutrients necessary to plant growth. The plants grew surrounded by an atmosphere free from impurities. Insect and fungous parasites did not cause much trouble. Today continuous cropping has destroyed much of the fertility of the soil. Increase in population and rapid means of communication have introduced into our midst parasites from all quarters of the globe. The atmosphere is no longer free from contaminations. These contaminations consist of the products of combustion of innumerable chimneys, domestic and factory, and from the various machines that line our railways and highways. Poisonous gases are poured forth into the air from many places of specialized and wasteful manufacture. Dust is also created and expelled into the air from many industries including those that manufacture cement. The enormous volumes of road dust which arise from our crowded highways must hinder to some extent the normal functioning of the plant life of our country sides.

The problem of atmospheric pollution has been one of sufficient importance to attract the attention of a number of investigators. Clevenger[1] conducted a survey in the vicinity of Pittsburg in which he determined the effect of soot on the surrounding vegetation. This survey was supplemented with laboratory investigations. He concludes that soot has a deleterious effect on vegetation on account of the clogging of the stomata. Bakke[2] conducted a similar survey in the vicinity of DesMoines in which he demonstrated that there were certain recognizable and definite belts of vegetation about a factory district. In zones immediately about such a district certain forms of plant life would not grow. Bakke believed that the damage to the vegetation was partially due to mechanical stoppage as well as to the chemical effects of certain poisonous gases present in the smoke. The effects of dusts settling from cement mills have been studied by several investigators. Anderson[3] determined that such dust prevented the setting of fruit. This injury he thought took place because the reaction on the stigmatic surfaces was changed inhibiting pollen germination. Peirce[4] demonstrated the effect of cement dust on the leaves of citrus trees in California by showing that five times as many starch grains were formed on the halves of leaves from which he had removed cement encrustations in contrast to the halves still encrusted. Parish[5] estimated that the lemon crop in the vicinity of cement mills was decreased one-fourth because of the interference of the cement encrustations with photosynthesis.

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[1] Clevenger, J. F. The Effect of the Soot in Smoke on Vegetation. Mellon Inst. Bull. 7. 1913.

[2] Bakke, A. L. The Effect of City Smoke on Vegetation. Iowa Agr. Exp. Sta. Bul. 145. 1913.

[3] Anderson, P. J. The Effect of Dust from Cement Mills on the Setting of Fruit. Plant World 17: 57-68. 1914.

[4] Pierce, G. L. The Effect of Cement Dust on Orange Trees. Plant World. 13: 283-288. 1910.

The survey which forms the subject of this paper was made in the vicinity of Oglesby, Illinois. Oglesby is situated in LaSalle County in the north central portion of the state. The city is located on the Vermillion River and is immediately opposite the famous "Deer Park" region. The principal industry at Oglesby is the manufacture of cement. Two large mills, the Marquette and the Lehigh are located at Oglesby. The Marquette is the larger of the two and both mills when operating at capacity do an immense business. The Marquette company mine their rock while the Lehigh company removes the overburden of dirt and then takes the rock from the surface. The latter company grinds the rock, mixes it with gypsum and clay and stores it in great bins. This mixture is taken from the bottom of the bins by gravity onto carriers and is transferred to the kilns where under forced draft the mixture is burned into a finished cement. It is during the latter process that most of the dust so evident over the surrounding territory is liberated. At the time of this survey the Lehigh company was having its kiln chimneys equipped with condensers which caught most of the dust from the stacks and returned it eventually to the kilns. These condensers should effect a saving to the company and protect the surrounding country from disfigurement. Three of the four kilns were so equipped and the fourth was in process of installation. The condensers that were in operation seemed to be quite efficient and the quantity of dust produced by this mill with the exception of the one stack was little. The Marquette Company did not have their kilns so equipped and great clouds of dust arose from the stacks of this plant.

The presence of the cement mills gives to the surrounding countryside an atmosphere that is unique. When one is several miles away the cement dust is visible as a cloud hanging over the city. As one comes into the region the dust becomes more evident; the dust clouds being of such volume as to partially obscure the light from the sun. It has an irritating effect upon the membranes of the eyes and nose. Clothes and shoes are quickly covered with a fine gray dust. I was told by one of the men in charge of the Lehigh mill that the grade about the mill had been raised two feet by dust accumulations since the mill had been in operation. Previous to my survey the season had been very wet and a heavy rain had fallen within the previous 48 hours. Nevertheless, within the zone affected by dust the characteristic gray coating was to be seen everywhere on the sides of buildings, roofs, telephone poles, trunks of trees, and upon the leaves of vegetation. I was informed that rain had little effect in removing accumulations from permanent structures. On these a hard cement coating is formed by the union of the dust and rain water which is practically indestructible by the ordinary atmospheric agencies.

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[5] Parish, S. B. The Effect of Cement Dust on Citrus Trees. Plant World 13: 288-291. 1910.

The purpose of the survey was: 1, to determine if plants were injured by such dust accumulations; 2, if injury was apparent, to determine whether some plants were more resistant than others to it; 3, to lay a basis for laboratory studies upon various phases of the problem.

It should be first noted that smoke injury is a minor factor in this region. The community is essentially rural. Oglesby has a population of 4,000 people living in scattered dwellings. The only smoke producers of consequence being the two mills situated a half a mile apart and the two railroads which pass through the center of the town. Little soot was detected in the dust accumulations and there was none of the characteristic tarry deposits found on the leaves such as may be found when smoke is abundant in the atmosphere.

Gardens in which all the usual garden vegetables were grown were found in the near vicinities of the mills. In fact one garden was found within the wire enclosure belonging to the Lehigh company. All gardens within the first two blocks of the mills showed a very evident lack of thriftiness on the part of nearly all of the plants. The plants were stunted, with many yellow leaves and some plants were positively deformed. A quarter of a mile east of the Lehigh plant, gardens again appeared to be normal although dust accumulations were plainly evident to a distance of a half a mile east of the mill. One gardener whose patch was one-fourth mile away from the source of the dust told me that he believed the cement dust to be an excellent fertilizer. Deleterious effects were much more evident upon both fruit and shade trees than they were upon other kinds of vegetation. Among the fruit trees, cherries, apples and pears were to be found within the quarter of a mile zone of the mills. Many of these fruit trees were entirely dead. Those that were alive apparently were having a difficult struggle for existence. Yellow leaves were common. Much dead wood was noted and there had been a dropping of leaves although it was early in the season. Many of the cherry trees were barren and those that were in fruit had but scanty crops. As a rule there was a better set of fruit on the side of the tree away from the mill. Cherry fruits were gnarled and imperfect. Outside of the zone of dust influence there was a uniformly even set of cherries on all trees and the imperfections noted within the zone were absent outside. Pear trees were more normal in their vegetative aspect but all were barren. Whether barrenness in this instance was caused by the dust can not be definitely stated as many trees outside of the zone were also barren. Apple trees were in fruit and as nearly as could be determined the fruit was set as well on one side as another. Peach trees within the quarter mile zone were barren and for the most part dead. Near the Lehigh mill the street trees consisted of Carolina poplar, boxelder, and catalpa. Of these trees the poplar appeared to be in healthiest condition, in fact showed no visible ill effects of its environment at all. Two blocks east of the Lehigh mill was found the first elm tree in this district. It was small. The leaves were yellow and curling. Elms were also found along the street which connected the two mills but for the most part they were much less vigorous and thrifty than the three street trees previously mentioned. At the eastern edge of the quarter mile zone was found two small groves of white and black oaks. In one of these groves 16 per cent of the trees were entirely dead while in the other, 50 per cent of the trees were dead. The western sides of the trunks of these trees were coated with cement dust. One-half mile east of the Lehigh mill another grove of oaks and shellbark hickories were found. In this grove there were no dead trees but much dead wood was present among the branches. Plants appeared to be normal beyond the half mile zone in this direction.

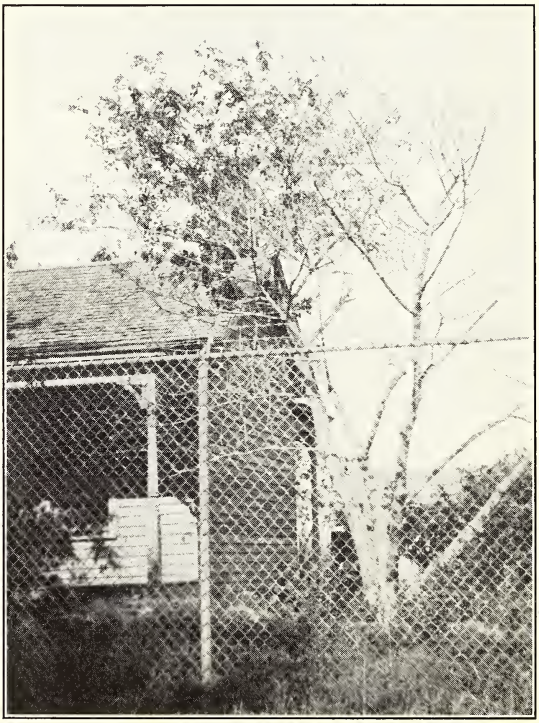

Fig. 1. Characteristic appearance of fruit trees near cement mills. Cement company's fence seen in foreground.

Conifers as a rule are considered to be more sensitive to atmospheric contaminations than are the broad leaved trees. At the gates to the entrance of the Lehigh company's ground were found two small decorative hemlocks. They appeared to be normal. These were the only conifers of any sort that were found within the affected zone with the exception of a small juniper that was entirely dead.

The affected zone did not extend so far to the west. Vegetation appeared to be normal in every respect one-fourth mile west of the

Lehigh plant. It is rather significant that the better homes are located on this side. A number of white pines in excellent condition were found in a dooryard six-tenths of a mile west of the mill.

Vegetation seems to be more affected in the vicinity of the Marquette mill. The space within the Marquette enclosure is almost a barren waste. Here and there a dead tree may be seen lifting up its barren branches over a landscape consisting of scattered patches of coarse grasses and weeds.

SUMMARY.

1. Many plants are seriously injured in the presence of large atmospheric loads of cement dust.
2. The zone of noticeable injury is comparatively small. The effect being greatest nearest the source of the dust.
3. The zone of injury extends farther to the east than to the west showing the influence of the prevailing winds.
4. Plants differ with regard to their tolerance toward this form of injury.

AIRPLANE PHOTOGRAPHY AND ECOLOGICAL MAPPING.

STANLEY A. CAIN, Butler University.

A comprehension of the problems involved in a study of plant succession of the zonation of plants is greatly facilitated by adequate maps. It is also quite true that possible solutions of some problems as well as some less apparent relationships are suggested by the preparation of maps or the pondering of available ones.

Frequently, helpful maps are not available for ecological studies. Road and land surveys mean little. Contour maps, which would be valuable, and cover-type maps are prepared for few places the ecologist chances upon in his studies. Not many ecologists are surveyors; nor do they have the necessary surveying equipment with which to work. As a result mapping naturally becomes a process of tying-in, off-setting, and scrap-paper trigonometry transferred to the out-doors, and is both tedious and inaccurate; or, as is frequently the case, the worker does without a map. Inaccessible places present a more acute problem; yet it is in just such places that airplane photographs facilitate the preparation of maps; indeed, only by such pictures is it practical to prepare them at all.

In so far as I know the only use of airplane photography in the study and mapping of vegetation was that reported by William S. Cooper of the University of Minnesota, at the 1925-26 annual meeting of the American Association for the Advancement of Science, at Kansas City[1].

The present work is in connection with "Some Ecological Studies of Bacon's Swamp" to be published later. Being a somewhat distinct problem it is presented in this separate form. Bacon's Swamp, with an approximate area of 30 acres, lies in the E ½, SE ¼ of Section 6, Washington Township, Marion County, Indiana. Its proximity to Indianapolis has long made it a favorite field of study and rendezvous of nature students, especially those of the city high schools and Butler University, and a tramping-ground for the Nature Study Club.

The interior of the swamp is occupied by a wet meadow composed predominantly of grasses, sedges, ferns, etc., with scattered patches of cat-tails and open water with such hydrophytes as *Saururus cernuus* (Plum.) L. and species of Polygonum. The wet-meadow is surrounded by a moat in which the water stands at a depth of two to four feet. The moat is filled with *Cephalanthus occidentalis* L. and is bordered with *Salix nigra* Marsh. The depth of the water and the dense tangle of the buttonbush in the moat makes the greater portion of the swamp inaccessible and accounts for the abundance of birds despite the nearness of the city. From the point of view of the ecologist, when confronted with mapping the plant zonation, these topographical and vegetational features present practically insurmountable obstacles. And as mentioned previously, it is in just such a situation that the airplane makes the whole process easy.

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[1] Cooper, W. S. Experiments in the Study and Mapping of Vegetation by Airplane Photography.

In correspondence Doctor Cooper has informed me that the material on which he reported at the Kansas City meeting "has not been published and probably will not be in separate form." He continued, "It was merely an incidental matter concerned in my study of the sand dunes of the Pacific Coast and their vegetation. Whatever results I have will be incorporated in my final report on that work and this will not be ready for at least two years."

The accompanying maps were prepared from pictures taken at an altitude of 5,000 feet. Five shots were necessary to cover the area of the swamp. Prints from the plates were fitted together so that the entire swamp was shown in one picture in its actual proportions. The camera was equipped with a 10-inch focal length lens. According to optical laws, and reciprocal triangles involved, each linear inch on the prints equals in feet one-tenth of the altitude at which the pictures were taken. For this particular work one-inch on the photograph equals 500 feet. The maps were enlarged to double dimensions so that the scale on the maps is one inch to 250 feet.

The enlargement of the map from the assembled photographs was a matter of manipulating a pantograph, a simple enlarging contrivance consisting of two sets of parallel bars so connected that any movement of the tracer, fastened at one end, is augmented at the other end where the pencil is attached. This instrument is adjustable so that different degrees of enlargement or reduction can be made.

The present work presents, perhaps, as severe a test as could be put to the process of mapping. The pictures were taken from a fairly high altitude, late in the fall, with only fair sunlight, and rather smoky atmosphere. Moreover, the vegetation of the swamp offered less contrast than most any other subject. Yet the essential proportions of the major associations are delineated. This is exactly what could not be accurately established from the ground except by an unreasonable expenditure of time and energy, to say nothing of the requisite skill. Whereas, a pantograph can be manipulated with ease and a copy or an enlargement of a picture produced quickly. The preliminary map thus prepared was taken into the field and the details, not apparent in the photographs, were sketched into the map by hand. The production of the final map was a matter of draftsmanship. Figure 1 shows the preliminary outlines as obtained directly from the photographs. Figure 2 is the final product derived from figure 1 by working in, from the field, the details not shown in the photographs.

In conclusion it may be said that airplane photography offers an accurate, quick, and cheap method of mapping and studying vegetation of inaccessible regions. This method will no doubt be utilized more and more for all sorts of mapping as planes become more numerous. Ecologists may do well to adopt the methods which our government and private enterprises have found indispensable.

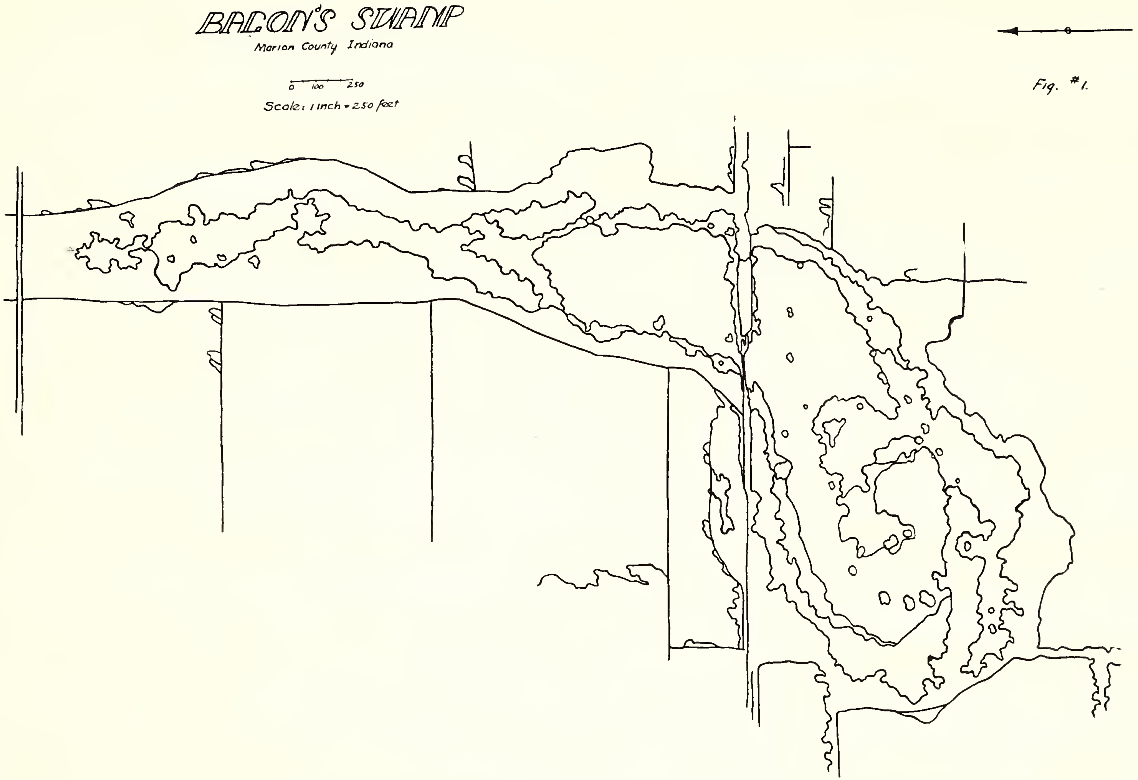

Fig. 1. Preliminary outlines as obtained directly from aerial photographs.

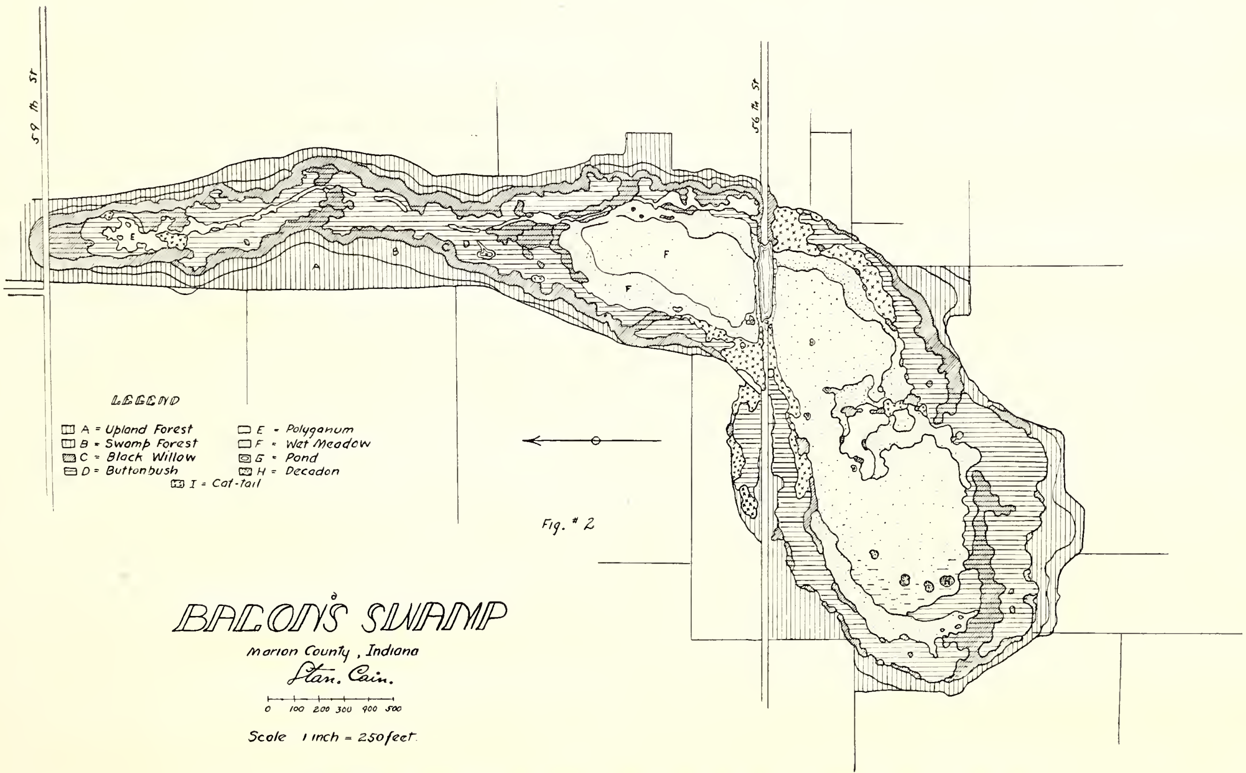

Fig. 2. Completed map derived from figure 1 and the addition of details from a field study.

PHOTOMICROGRAPHY AS AN AID TO TEACHING AND RESEARCH IN BIOLOGY.

Edwin J. Kohl, Purdue University.

Photomicrographs are the chief support of the instructor in any course in plant anatomy besides the preparations used; they are the very means of illustrating our researches in morphology, in pathological anatomy, in spore germination studies, etc., if the photomicrographs are well made. Undoubtedly it requires fairly good equipment in this work if the best results are to be obtained.

The lighting system may be considered first. By the use of daylight, good photomicrographs can be made but the exposure is long, especially so, if light filters are to be used. Daylight varies considerably. An arc is perhaps the best type of illuminant and on direct current is unusually satisfactory. If the arc is used on alternating current, results will not be worth the effort required to secure a constant and uniform field of illumination. It may be added though, that excellent photomicrographs can be made with a 4 ampere arc and an 8 ampere resistance on alternating current, and that this type gives a very steady and fairly uniform field of illumination. The 108 watt, 6 volt ribbon filament Mazda lamp and transformer used with 110 volt alternating current, is perhaps the best lighting system for general use. An aspheric condenser is best used with this light.

A microscope with the ordinary achromatic objectives and Huygenian eyepieces can be used. Far better results are to be had with apochromatic objectives and hyperplane or periplane eyepieces.

The sub-stage condenser should be aplanatic if a good, uniform field of illumination is expected. This condenser is separable. The lower unit is used for the lower power objectives, and for the higher power objectives the upper unit is replaced. For the very low power objectives such as the 24 mm., 36 mm., and 48 mm. microtessars, summars or planars, no sub-stage condenser is used, since the aspheric condenser in the illuminating stand suffices. A diaphragm with markings is inserted in these objectives by the manufacturer. If the illumination is so bright as to require exposures shorter than one second, a piece of ground glass or several thicknesses of lens paper placed in the light path will give a satisfactory reduction in intensity. For oil immersion objectives, oil is placed on the condenser and in contact with the lower side of the slide. Cedar oil is not to be preferred. Any clear paraffin oil is just as satisfactory. This is true also for objective immersion oil.

The bellows and stand for the camera can be purchased from any of the optical companies (fig. 1). Any plate camera will do, for one need only remove the lens and shutter. The bellows must have a light proof union with the eyepiece.

"Proc. Ind. Acad. Sci., vol. 36, 1926 (1927)."

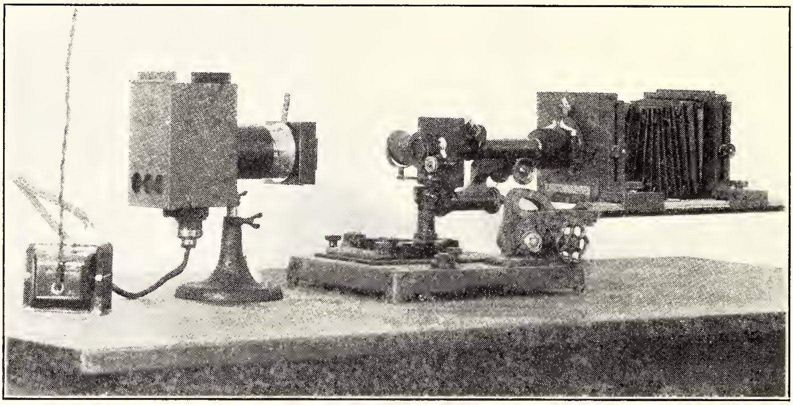

Fig. 1. Photomicrographic equipment assembled.

Any lighting system where artificial light is used must be centered and focused. The light is centered upon the substage condenser and diaphragm so that the area of greatest brilliancy of the light falls upon the substage condenser. The light is moved back and forth to find this place, and the aspheric condenser is properly focused. For the 16 mm. objective, the upper unit of the aplanatic substage condenser is removed (fig. 2). With the diaphragm completely closed and the ocular removed, we examine the light projected on a white piece of paper, held in the position of the ocular and a few inches back from the body tube (fig. 3). The light area should be a perfect circular are of uniform illumination. If it is not, rack the substage condenser back and forth until a perfect area free from any color is obtained. If the lighting system and microscope are in perfect alignment such a light area is soon to be found. A circle of brighter light on this light area aids in focusing the substage condenser. The ocular

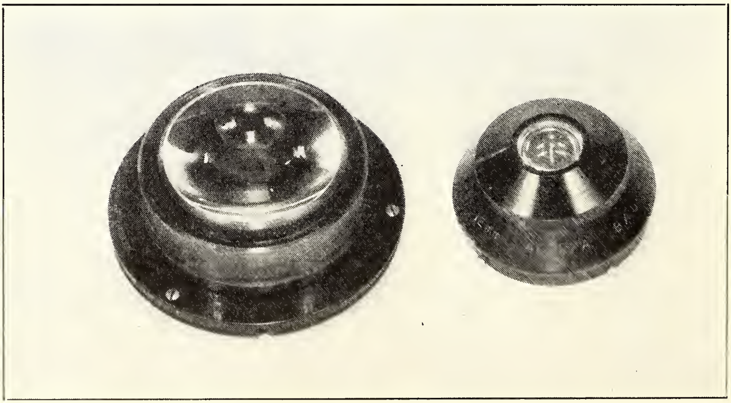

Fig. 2. Aplanatic substage condenser removed and separated. The larger unit is for low power work; as a doublet it is used for high power work.

is replaced and the illumination is examined through it on a white piece of paper in the same manner with a completely closed diaphragm. The object may now be placed upon the stage and focused upon in the same manner again. Then the bellows are drawn into place and the ground glass is focused upon and examined. The field of illumination will be as good as can be had, and can not be improved by examination of the ground glass area, since very slight discrepancies of uniformity over so large an area are not as readily discerned as on a small area just a few inches back of the ocular.

The diaphragm aperture at which the exposure is made has much to do with definition. If too small an aperture is used the finest definition is destroyed. It follows also that a loss of depth results with too wide an aperture. So a medium aperture is to be desired and the examination of the ground glass will determine what aperture one wishes.

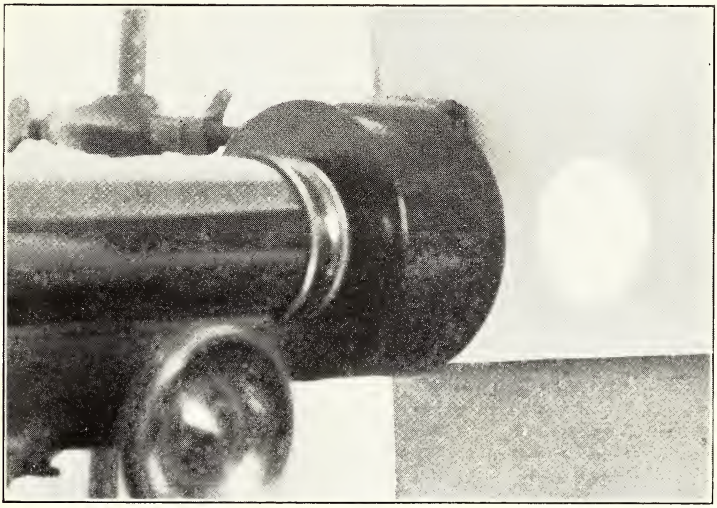

Fig. 3. Focusing the light through the ocular on a piece of paper held back of the ocular.

Exposure varies with the aperture used and with the distance the ground glass is extended beyond the ocular. It is both desirable and necessary to have the bellows extension bar ruled off in units of length. The camera stand of most optical companies is marked in centimeters. On the other hand, the diaphragm is never marked, and so one must either judge by the intensity of the illumination on the ground glass each time to determine the exposure or stops must be marked for the diaphragm, so that exposure in relation to aperture can be standardized. These stops can be fixed since there is a lever that actuates the diaphragm of the substage condenser (fig. 4). If there is no lever, some other means can be devised. If correct exposures are found for one's favorite brand of plate, record can then be kept from the markings both on the diaphragm and the bellows draw bar. For the same substage condenser unit, and the same aperture of the diaphragm, exposure varies as the square of the magnification. If the upper unit of the condenser is replaced for a 4 mm. objective or a 1.9 mm. objective, then the exposure must be ascertained at some magnification and diaphragm aperture again, and the variations of exposure above or below that magnification accounted for on the rule as stated, i. e., exposure varies with square of the magnification.

In order to have relatively good contrast or a contrast greater in monochrome value than appears in polychrome on the triple stained slide, Wratten or similar light filters may be used. So then, it follows that a green filter on a safranin stained cell wall will cause the red to be darker. However, in xylem cell walls detail is thus frequently lost, due to too great a contrast in monochrome, and so an orange or even a light red filter is frequently desirable. The required contrast is to be had by a prolonged development if necessary. The ordinary orthochromatic plate or panchromatic plate emulsions do not give quite sufficient contrast even with prolonged development, so as to be of absolutely satisfactory use in photomicrographic work, although fairly good work can be done on these plates. The Wratten "M" plate is far superior in that it is panchromatic and a contrast plate of good speed.

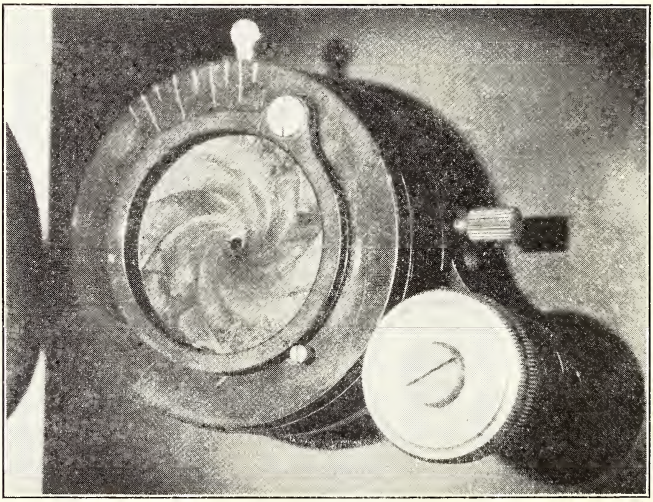

Fig. 4. The substage diaphragm closed. Stops are marked on the plate.

The developer to be used for Wratten "M" plates is given in the directions accompanying the plates. The following developer was found to be particularly good. It keeps well and can be used repeatedly. However, after development the developer used is discarded, even if only one plate is developed, in order that a standard practice may be maintained. The developer[1] is as follows: hot water (100° F.), 2 liters; Elon (Metol), 0.6 grams; sodium sulphite, anhydr., 80 grams; hydrochinone, 12 grams; sodium carbonate, anhydr., 38 grams; potassium bromide, 1.8 grams; citric acid, 1.4 grams; and sodium bisulphite, 3 grams. Use at full strength at 65° F. For printing on a No. 2 contact paper about six minutes is the correct time of development, although if less contrast is desired even four and one-half or five minutes will not result in any great flatness. Development and fixation are done in total darkness, directions for the use of a green safelight from the manufacturer nothwithstanding. It is not possible to determine a relatively sufficient end point during development by means of a green safelight; so none is used.

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[1] This formula was furnished through the kindness of Dr. M. E. Diehmer, University of Wisconsin, Madison, Wis.

A FUNGUS GROWING IN "MINERAL OIL."

ROBERT HESSLER, Indianapolis.

On November 28, 1925, a middle-aged patient, an intelligent, trustworthy man, was given a "Pinoleum" outfit for spraying the nares, morning and evening; at the same time he received a considerable supply of plain Oil of Petrol, known also as "Mineral Oil"—not an oil at all but a paraffine; the repeated replenishing soon diluted the original green tinctured and aromatized "oil" to the vanishing point.

On April 18, 1926, that is nearly five months later, the patient called attention to the presence of a white flocculent mass suspended in the oil, near to and at times touching the bottom of the glass container; it resembled a tuft of fine cotton, about the size of a large coffee bean. He was going to throw it out—feared it might clog the tube. "Ah, wait a moment," I exclaimed, "let me examine it." A flocculent white mass. "Did any cotton get in?" "No." A closer examination with a hand lens revealed filaments extending in all directions. "And you say it has grown, developed in the oil?" "Yes." That upset my ideas in regard to metabolism, the relative role of water, food and air. First thoughts were along the line of the perverted metabolism of the hot water or geyser alga of the Yellowstone Park, but a microscopical examination revealed spores. Ah, a fungus,—an opinion confirmed by several botanists to whom some of the material had been given; apparently an Aspergillus, without venturing an opinion as to the species. One man expressed the idea that it might be a new species on account of this peculiar and unique habitat.

A bibliographic research in the rather limited literature at my command proved negative, likewise personal inquiries among men who might have had experience; one biologist bluntly expressed his belief that life under such conditions was impossible. Yet here is the specimen!

The following statements from a paper on "Function and Design," by Prof. J. B. Leathes, before the British Association for the Advancement of Science, (*Science*, October 22, 1926, p. 387) may be of interest in this connection:

> "Life is exhibited only in aqueous systems, containing unstable, perishable combinations of carbon with hydrogen, nitrogen, sulphur, phosphorus and oxygen, in the presence of certain inorganic ions, those which are present in the sea, the native environment originally of all forms of life . . . the molecules that enter into the composition of living matter exhibit the phenomena of life only when permeated with water molecules exercising the kinetic activity of the liquid state."

Theoretically considered, water is necessary. Nutrients are necessary, although a small speck of dust, passed in while using the atomizer,

"Proc. Ind. Acad. Sci., vol. 36, 1926 (1927)."

would suffice for a small colony (the mass appeared as one large single colony), yet such a dust particle would at once be permeated or saturated with the "oil" and rendered insoluble in water—and on the assumption that water is necessary to carry on metabolism, this "oil" would have to be leached out, so to speak, before the food or nutrient would become available. "Mineral oil" is a wholly artificial product due to man's activity, unknown until only a few years ago. But after all the process of adaptation to such a medium may be simple.

Through correspondence a microbiologist was finally found who was both competent and willing to undertake an investigation.

I have before me a letter from Dr. Charles Thom of the Microbiological Laboratory of the Bureau of Chemistry, U. S. Department of Agriculture, from which I quote:

"My interpretation of your observation follows: Oil in a substratum may be regarded as an inert substance so far as the microorganisms of this group are concerned. When colonies of fungus develop in a grease or oil, it is practically always attributable to the entrapment of little globules of watery substance in a body primarily consisting of oil. We have known, for example, colonies of mold to develop in barrels and pails of grease. In those cases extremely careful analysis shows that little globules of water have been entrapped in the grease, carrying with them sufficient nutrients to produce small colonies of mold.

"Your observation is sufficiently interesting so that we will be glad to take note of the sample and make a careful examination and cultures from it and let you know whatever we find."

Summary and Observations. The original "oil" in the atomizer was tinctured a light green and aromatized with essential oils.

The original "oil" in time reached the vanishing point through repeated additions of plain "Oil of Petrol."

The atomizer was used twice a day, morning and evening, at home, under ordinary room conditions, in a closet and not exposed to direct sunlight. While in use there was considerable pressure on the oil and agitation through handling,—conditions very different from usual culture conditions.

The white, delicate filamentous or mycelial mass was suspended in the "oil" near the bottom but movable.

Dust particles might naturally be expected to enter through the air forced in while using the atomizer. Some water or moisture might also gain entrance, but the oil itself was clear, no globules visible.

The term "oil" should be fully considered. Mineral oil is a distillate, a paraffine, a substance wholly foreign to living matter. When it permeates a dust or food particles is a living organism able to leach it out?

In time the white mass turned dark and shriveled. Spores are abundant.

Finally, I have placed some of the original material in small vials. If any of you care to work on this material, you are welcome to it.

SYMPTOMS AS INDICATORS.

ROBERT HESSLER, Indianapolis.

In its wanderings through the mazes and labyrinths of human experience and knowledge the mind may be represented as a traveller, often wandering aimlessly, but in the case of the searcher after truth the mind is always lured by some indication which becomes to it an incentive as well as a guide.

Indications or indicators may be said to be the advance agents by which the scientific mind is guided in its work.

An indicator thus may point the way to the revelations of a subject and also becomes a real index when it establishes the location of the data acquired.

Thus to the scientific type of mind every phenomenon of nature, either subjective or objective, becomes an indicator and is used as a part of the data for the establishment of theory and practice.

In this paper the subject of "indicators" is limited to the realm of the reactions of man usually spoken of as symptoms; and these two words, symptom and indicator, will be found to involve almost the entire gamut of the mental reactions of man.

It is with a full realization of the complexity of the subject that this abstract is presented, for I am not unmindful of the remarks made to me by Dr. Stanley Hall in discussing his own experiences, that in working in neglected fields or in new fields one at first finds many persons interested in a general way; later, but few persons can be approached on the deeper and more intricate phases of the subject, until at last when the manifold complexities and wider range come under intensified intellective process, one stands alone to continue the work.

A glance at this chart (a large chart was shown) may enable you to get some idea of the ramifications and complexities of the subject. This chart represents a chronologic outline and topical details of the mazes through which I was compelled to wind my way in order to reach the position and viewpoint that enabled me to arrive at certain conclusions, a few of which are briefly referred to in this abstract. A good chart should have a place for every item, observation or ascertained fact. A good working theory should find a place for the ascertained facts.

Origin and Development of the Subject. At the age of 16, when my father died, the term symptom came definitely into my own vocabulary, brought about by inquiries regarding his illness. Later when I entered college I became acquainted with the term indicator, in connection with laboratory work in chemistry. From then on the term symptom was associated in my mind with bodily activities and the term indicator with physical phenomena. It was not until I entered medical college that I became acquainted with the term sign. Later

I acquired a discriminatory understanding of indicator, symptom, sign and test, in considering both man and his varying environment.

Differentiation and Definition. With reference to its use in this paper, an indicator is a condition or reaction subjective or objective which serves to aid the mind in the interpretation of phenomena associated with human activity.

A symptom is a subjective indicator; a sign is objective. Thus the feeling of lassitude, a headache, a buzzing of the ears, are all symptoms that may aid in locating and understanding the cause; whereas bloodshot eyes, a twitching of the muscles, and a swollen joint are signs, which although obvious enough may in reality be of secondary importance as etiologic factors.

A test may be considered in a general way as an experiment made for the purpose of determining and evaluating a subjective or objective reaction.

With regard to symptoms, as of all other phenomena, we can and must ask the eternal Where, When and Why? Anyone can answer as to place and time, but the why may be difficult.

Although the theory of Coniosis[1] and the interpretation of symptoms from the biologic and evolutionary viewpoint may become a very practical guide in regard to the where, when and why of symptoms, yet at the same time we should keep in mind the exceptional case, the exceptional tenth case, that may be "purely medical," or that may belong in the province of the psychoanalyst.

Biologic Interpretation and Application. Voluminous treatises have been published on symptoms, but they are medical books and deal with diseases. Doctors do not as a rule speak of "symptoms of health," although under our definition a condition of health is just as vital a subject for investigation as a condition of disease, for as a matter of fact one condition is in reality only thoroughly explained in the negative of the other.

Therefore it will be seen that the approach to an adequate understanding of the conditions that produce or cause disease must eventually find an avenue through an appreciation of what constitutes health. This is evidenced by the changes in medicine itself, which is gradually undergoing an evolution. More and more attention is given to the individual as an organism than to the disease as an entity. Etiology, namely causation, is considered more and more from the viewpoint of environment and of vocations and occupations, thus emphasizing the biologic interpretation and laying stress upon the importance of health supervision. With increased sanitation, improving the environment, less attention will be necessary for personal hygiene and still less for medication.

Problems are endless, and often simple observations will help in their solution. Brief mention might be made of a few such problems:

What is a proper schoolroom temperature? What are the subjective symptoms and objective signs of an improper temperature? The great discrepancy of opinions must be harmonized.

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[1] See 'Coniosis," Proc. Ind. Acad. Science, 1911, pp. 415-437.

Again, under what conditions do we feel chilly, and when do we want the home and houses overheated? Definite observations are necessary.

Further, the expression "I don't feel comfortable in a crowd" is frequently heard. Some people avoid crowds. Some go out of crowds "red as a beet," and others "white as a sheet."

Again, under what conditions does a man acquire knotty finger joints? Some individuals are sorely afflicted.

And, again, under what conditions are we under tension, with the jaws set? Tension and relaxation are names of important symptoms under city life, often reaching the point of visible signs. The where, when and why must always be sought.

The general sense organs, involutions of the ectoderm, keep us in touch with the external world and affect the sensorium; but we often forget that the so-called sympathetic nervous system co-ordinates the internal economy and has its own method of warning us that something is wrong, as for instance with the general metabolism. Generally we neglect the gentle warnings, and then appear surprised that assumed symptoms of health or of ill health are actually symptoms of disease.

Adjudication and Evaluation. The student of ill health, and of symptoms thereof, soon learns that rarely does a person come to him for advice on health, and only occasionally on account of a definite specific disease; but the majority of his cases—his material for study—is made up of those who complain of one or more annoying or distressing symptoms, relief from which they usually feel can be obtained from a "little medicine." Each patient of this kind has a more or less distinct idea of the nature of his ailment, and has faith in the efficacy of medication. Today there are many "new-fangled modes of treatment," as by various forms of light, especially for the relief of pain.

Although these patients are tolerated professionally, the question of properly evaluating the judgment of the patient becomes an interesting one to the conscientious physician, for he knows that these persons frequently become "old chronics" who contribute so largely to the fertility of the soil upon which the isms and pathies luxuriantly thrive, supplying the generous field for exploitation by quacks, and healers and curers, and the patent medicine man.

The Use and Abuse of the Term Symptom. This brings us to a consideration of the use and abuse of the term symptom. It is the aches and pains, the subjective annoyances and distressing feelings and sensations that drive persons to the point of applying for treatment and to the taking of medicine. Pills and powders, elixirs and tonics, and even health foods, are not in the great majority of cases a matter of a doctor's prescription. It is a rare instance where one finds an individual who is not an occasional self-prescriber, and the papers and magazines, page after page, testify to this condition by the cleverly worded appeals to this inordinate desire for relief through self-medication.

An analysis or critical examination of patent medicine advertisements will reveal a catering to this desire for relief from annoying and distressing symptoms, which the sufferer may regard in the light of actual disease. Frequently these symptom names are so cleverly juggled as to present to the minds of the ignorant and unwary a picture of a condition associated with a disease, mainly a name made perhaps familiar through these very advertisements; and by a confusion of the terms symptom and disease the seed is sown which permits the idea to grow that relief and cure are synonymous.

Of course we say the purchaser of quack medicines is ignorant. But how should he know better? Who had charge of his education? Symptom is a word rarely to be found in the index of educational books. Curiously enough, the man who has been taught about the stars and the Milky Way in college, when the psychologic moment comes may also purchase an advertised medicine.

Taking a wider view of what is implied by the expression "The Patent Medicine Problem," the conviction forces itself on the student that Indiana is still in the "Patent Medicine Stage"—seeking to give relief to the afflicted, acting the Good Samaritan in binding up wounds, but making little or no effort to prevent the infliction of new wounds.

Indiana has not a single institution or school for the training of sanitary engineers, or for the proper training of sanitarians, hygienists and teachers of so-called "Physiology and Hygiene," a training that is not limited to mere textual recital, but one that is supplemented and enriched with the lessons from life histories, with the actual material from euthenics, eudemics and eubiotics to serve as a basis for emphasizing the lessons.

Therapeutics itself is gradually reaching the stage of a science; much simple observation and much experimenting under controlled conditions is still required. Alas that therapeutics should today be still the plaything of the ignorant. The discovery of any new element at once brings up questions: "What is it good for?" "What symptoms will it relieve and what diseases will it cure?"

Writers on therapeutics speak of the indications for the use or application of remedies. The old books gave long lists of indications; today the lists are getting shorter and shorter in the case of real remedies, but growing longer and longer in the case of remedies, or pseudo-remedies, for "conditions"—in short, for the symptoms of our "Triad of National Diseases," as found here, right at home; and to which I called attention in "Coniosis," printed in the Proceedings of this Academy for 1911.

The Necessity of the Biologic Viewpoint. This deplorable state of affairs in regard to the nature and significance of symptoms can be largely corrected through a study of life histories. If lessons in regard to the rise and decline of nations can be learned from history, why should not we also be able to learn lessons in regard to the rise, the work, the ills and decline of the individual by a study of biography, real life history, and not mere "book-chat," for "the proper study of mankind is man."

We must distinguish between reactions that represent normal and abnormal conditions of the human body. More attention must be given to reactions that represent health, for health is really not a stable condition. Health is a variable state of the organism, of body and mind. There are all sorts of qualifying terms, such as good, excellent and best. On the other hand, we have poor, bad, miserable, precarious, etc., and we even hear of those who have "lost their health," or "regained their health." Therefore it is no wonder that Emerson grew impatient and said "Talk Health," in place of the everlasting talk about symptoms and diseases. Yet, paradoxically enough, perhaps nine-tenths of the common symptoms of daily life are beneficent, are to be looked upon as warnings from nature, and are to be heeded; but the correct interpretation of these symptoms requires the knowledge growing out of the lessons from life histories, thus emphasizing this study as a contribution to the solution of health problems.

Commonly there are only two categories that are used by both the laity and the physician, namely, health and disease. But where one shades off into the other nobody knows.

The modern laboratory method has given rise to many tests, especially to indicate the presence or absence of specific diseases, but complaint has been made of an over-nicety, an over-refinement and the neglect of simple observations.

We need an American System of Medicine, one that concerns itself more and more with health and health supervision, with the where, when and why of symptoms and how to avert, avoid and prevent ill health; and this requires that the "naturalist type of mind" return to medicine. This type is represented by a small class, few in any community or average county; and in an earlier day this class naturally "took to medicine." However, since the teaching of natural history sciences has become so common in the colleges and high schools, this type of mind is neglecting medicine; and as a result those who today take up the study of medicine are usually not those with the naturalist propensities, and therefore the biologic viewpoint is neglected. Too many present-day physicians still seek a solution in the midst of the complexity of the city; or becoming discouraged on account of the difficulty of disentangling factors, they abandon all efforts at a solution,—and so the isms and pathies of all kinds flourish.

I venture to say, after a long study, that nine-tenths of the common symptoms today are indicators of an abnormal environment. The other day I passed a street thickly strewn with cinders and ashes; these were being reduced to dust under street traffic and the dust whirled about by speeding automobiles, resulting in irritation of mucous membranes. Then I passed a school playground formerly covered with cinders, very productive of "black spit," but now covered with crushed limestone. Gritty dust is an irritant, and common mucous catarrh is a normal, a physiologic reaction, a process analogous to tear formation in the eyes when foreign matter enters. But with infection about a simple catarrh becomes purulent, just as a simple cold may become purulent and "hang on," and that in turn is followed by scarring, a sclerosis, all of which is very interesting to the pathologist and to the clinician interested in the production or causation of symptoms.

We are living in the days of ill health rather than of definite or specific diseases. The number of cases of the latter, as reported in the

Monthly Bulletin of the State Board of Health, is so small that in any average county one, two or three physicians would not be overworked in attending to them, and yet such a county may have perhaps 50 physicians. What keeps them busy? While correcting and rewriting these notes, the morning's mail brought me seven pieces of proprietary medical literature, six of these related to remedies for the relief of symptoms, the seventh relates to acute articular rheumatism, really a rare disease and for which there are a hundred and one remedies, nearly all variations of the original salicin or salicylate method.

A nose and throat specialist was very frank when one of my old patients complained that he was not being cured; he said to him, "there are some conditions which we cannot cure, but we keep on treating the patient as long as he comes to us." No wonder biographies contain so few encomiums on the medical profession.

Those who lead a simple life, life under clean air conditions especially, are apt to have few symptoms, the opposite being true of those who live under complex city conditions. One may in this connection refer to the Life and Letters of Huxley, where there are over 200 references to health and ill health, with mention of but one specific disease,—influenza. These references are to varying bodily and mental conditions,—many while in London, few or none while in the open country. Page 154 of volume I is a striking page; half reveals life under city conditions and the other half gives the picture of country conditions.

Huxley's life itself reveals the fact that health in the great majority of cases is an indicator of the environment, good health indicating a good environment, bad health a bad environment. This demonstrates the importance of offsetting indoor and city life by life in the open, a practice indulged more and more by those who are wise and observant. Charles Dickens may be cited as a classical case of the value of offsetting. Much can be learned from biographies.

The organism must of course change with every change in the environment, and it must not be forgotten that the environment is conditioned by both subjective and objective factors. What a man reads is as much a part of his environment as what he eats, and the conditions under which he reads and eats are surely environmental factors, as potent and exacting as the conditions under which he works and sleeps. The two extremes of health and disease are rarely as sharply divided as two lots by a city fence. Frequently the transition is that from daylight to darkness or darkness to light. The twilight hour of the organism is the transition both from health to disease and from disease to health. The student of symptoms from the biologic, the naturalist and evolutionary viewpoint speaks of three categories: ease, unease and disease. What is commonly called "health" constantly fluctuates between ease and unease, rarely touching actual disease at all in the life of the present-day individual. But in the end all must die, and usually from some terminal infection, actual disease, and any philosophy, any theory, any religion that neglects to give discriminatory attention to symptoms, signs, indicators and tests—well, comment is unnecessary to any one who has had some training in biology.

RECORDS OF INDIANA DRAGONFLIES—II[1]

B. ELWOOD MONTGOMERY, Poseyville, Indiana.

This is the third series[1] of notes on Indiana dragonflies to be published since Williamson's annotated list[2] and it records captures made in 1925 and 1926.

Only captures of the less common species, or captures which extend the known range, either seasonal or regional, of species are given in this paper.

Little collecting was done in 1925, but during the dragonfly season in 1926 a party was in the field almost weekly. The object of each trip was usually to secure one or two of the rarer species but collections were made and notes made on almost all of those seen. The collecting party almost always included E. B. Williamson and J. H. Williamson, who were frequently accompanied by one or more of the following: Robert Engeler, Eli Captain, Paul Cook, and myself. Prof. J. J. Davis collected the specimens recorded from Crown Point. I made the captures recorded from the southwestern part of the state. A few specimens taken by other collectors are listed with the collector's name in parentheses following the record.

On September 3, 1926, Paul Cook collected the dragonflies found at a tile yard pond at Poneto, Wells County. The following species were secured: *Lestes forcipatus,* one male and six females; *Enallagma civile,* one male; *Enallagma signatum,* two males; *Ischnura verticalis,* five males and ten females; *Anomalagrion hastatum,* nine males and six females; *Sympetrum vicinum,* one male; *Celithemis elisa,* one male. A male of *Plathemis lydia* was seen. *Celithemis elisa* was probably a visitor and not a native of the pond.

The numbers of Williamson's annotated list are used in the following list of species.

3. *Agrion maculatum* Beauvois. Buttonwood swamp, near Cowan, Delaware County, July 11, 1926.

9. *Lestes forcipatus* Rambur. Common at pool in gravel pit near Lafayette, May 26, 1925. Several pairs were observed in copula. The female oviposites in the leaves of cattails, and the process is not essentially different from that which I have described for *Lestes congener*[3] although the interesting co-ordinated movement of male and female noted in that species was not seen, the pair flying to another leaf after eggs had been placed at short intervals for several inches down the

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[1] Williamson, E. B. Notes on Indiana Dragonflies. Proc. Ind. Acad. Sci. 1920, pp. 99-104.

Montgomery, B. Elwood. Records of Indiana Dragonflies. Proc. Ind. Acad. Sci. 1924, pp. 383-389.

[2] Williamson, E. B. An Annotated List of the Odonata of Indiana. Misc. Publ. No. 2 of the Uni. of Mich. Mus. of Zool. 1917. 12 pp. 1 map.

[3] Proc. Ind. Acad. Sci. 1924, pp. 383-384.

"Proc. Ind. Acad. Sci., vol. 36, 1926 (1927)."

leaf rather than walking up the same leaf to repeat the process. Swamp, near Cowan, Delaware County, July 11, 1926.

11. *Lestes rectangularis* Say. Swamp, near Cowan, Delaware County, July 11, 1926.

12. *Lestes uncatus* Kirby. Swamp, near Cowan, Delaware County, July 11, 1926.

15. *Argia apicalis* Say. Big Creek, Posey County, August 19, 1925; Foote's Lake, Gibson County, August 28, 1926; Wabash River, below Markle, Huntington County, August 29, 1926.

16. *Argia moesta* Hagen. Wabash River below Markle, Huntington County, August 29, 1926.

17. *Argia sedula* Hagen. Wabash River below Markle, Huntington County, August 29, 1926.

21. *Enallagma antennatum* Say. Near Vincennes, July 18, 1924; Pigeon River, Lagrange County, July 5, 1926; Wabash River below Markle, Huntington County, August 29, 1926.

25. *Enallagma civile* Hagen. Tile yard pond, Monroe, Adams County, September 15, 1925; Blackman Lake, Noble County, August 8, 1926.

27. *Enallagma divagans* Selys. Pigeon River, Lagrange County, and "Old Canal," Noble County, July 5, 1926.

29. *Enallagma exsulans* Hagen. Pigeon River, Lagrange County, July 5, 1926; Foote's Lake, Gibson County, August 28, 1926; Wabash River below Markle, Huntington County, August 29, 1926.

30. *Enallagma geminatum* Kellicott. Miller Lake, Noble County, July 5, 1926; Narrows Lake, Noble County, August 22, 1926.

33. *Enallagma vesperum* Calvert. Foote's Lake, Gibson County, August 28, 1926.

34. *Enallagma signatum* Hagen. Foote's Lake, Gibson County, August 28, 1926.

35. *Enallagma traviatum* Selys. Foote's Lake, Gibson County, June 12, 1925; Miller Lake, Noble County, July 5, 1926.

36. *Nehalennia gracilis* Morse. This rare species which has been recorded from the state but once previously was taken on two occasions in 1926. Eleven males and four females were captured at Lane Lake (formerly called Case Lake), Lagrange County, July 18; 21 males and three females of the more common *Nehalennia irene* were taken at the same time and place. August 8, 14 males and five females of *gracilis* and one male of *irene* were captured along a creek flowing into Oliver Lake, Lagrange County. In freshly killed specimens the females, which may be distinguished by the form of the prothorax, may be more readily separated by color differences—the sides of the thorax are greenish-yellow in *irene*, blue in *gracilis*.

38. *Amphiagrion saucium* Burmeister. Creek flowing into Oliver Lake, Lagrange County, August 8, 1926.

39. *Chromagrion conditum* Hagen. "Old Canal," Noble County, July 5, 1926.

41. *Ischnura posita* Hagen. Gravel pit, near Lafayette, May 26, 1925; Wabash River below Markle, Huntington County, August 29, 1926.

43. *Ischnura verticalis* Say. Gravel pit, near Lafayette, May 26, 1925; tile yard pond, Monroe, Adams County, September 15, 1925; swamp, near Cowan, Delaware County, July 11, 1926; Crown Point, August 5, 1926; Wabash River below Markle, Huntington County, August 29, 1926.

45. *Tachopteryx thoreyi* Hagen. Clifty Falls, Jefferson County, May 13, 1925, attracted to light about 7 p. m. (H. F. Dietz.)

51. *Ophiogomphus rupinsulensis* Walsh. Pigeon River, one mile east of Mongo, Lagrange County, July 5, 1926; Cedar Creek, Allen County, July 25, 1926, (Eli Captain).

52. *Erpetogomphus designatus* Hagen. In cultivated fields and less commonly in waste land grown up with giant ragweed and other plants, along Wabash River, Gibson County, nearly opposite Grayville, Illinois, August 31 and September 2, 1926. On the latter date *Gomphus plagiatus* was found associated with it in the fields grown up with weeds.

56. *Gomphus fraternus* Say. Cedar Creek, Allen County, July 25, 1926, (Eli Captain).

59b. *Gomphus plagiatus* Selys. See note under 52, *Erpetogomphus designatus.*

63. *Gomphus submedianus* Williamson. Foote's Lake, Gibson County, June 12, 1925. A few individuals of this species were noted flying about over the edge of the water, and alighting on sticks protruding from the water or resting on bare rocks along the shore. Two males and one female were captured.

65. *Gomphus ventricosus* Walsh. West Lafayette, May 20, 1925. A male picked up from a walk on Purdue University campus at noon, (R. W. Montgomery).

68. *Dromogomphus spinosus* Selys. Pigeon River, near Mongo, Lagrange County, July 18, 1926. Hovering over stream and alighting on leaves of bushes overhanging or at edge of water.

71. *Basiaeschna janata* Say. Near West Lafayette, May 12, 1926, (H. W. Li); Miller Lake, Noble County, July 5, 1926.

72. *Anax junius* Drury. Several individuals of this species were seen at "Happy Hollow," a wooded glade about a mile north of West Lafayette, March 24, 1925. A pair was captured at a gravel pit near Lafayette a week later. This date extends the known seasonal range of this species in the state to about six and one-half months—a greater period than the range of any other dragonfly in Indiana. Tile yard pond, Monroe, Adams County, September 15, 1925; Crown Point, August 5, 1926.

78. *Aeshna umbrosa* Walker. At pools along Pigeon River, Lagrange County, September 19, 1926, and in glade along Wabash River below Markle, Huntington County, August 29, 1926.

79. *Aeshna verticalis* Hagen. Marshy grass and sedge flat along creek flowing into Oliver Lake, Lagrange County, August 8, 1926.

80. *Nasiaeschna pentacantha* Rambur. This species was found in numbers at Foote's Lake, Gibson County, June 12, 1925. Not less than 15 individuals were seen patrolling the shores or darting about among the leaves of spatterdock. A female, unaccompanied, was observed

ovipositing in the upper surface of a spatterdock leaf. Pigeon River, three miles east of Mongo, Lagrange County, and "Old Canal," south of Rome City, Noble County, July 5, 1926.

85. *Macromia taeniolata* Rambur. Foote's Lake, Gibson County, August 28, 1926. This species has been noted at this lake, which is apparently an old river channel, during July and August for the last three years.

94. *Somatochlora linearis* Hagen. Two males and one female were taken at a small creek in Lafayette Township, Allen County, July 25, 1926. Almost 30 specimens of this species were captured along this creek in 1924, but during the winter of 1924-1925 the trees were cut from along the better portion of the creek. On July 25 the stream was very small at the place from which the trees were not cut and contained only small pools of water with no above ground flow.

99. *Libellula luctuosa* Burmeister. Lane Lake, Lagrange County, July 18, 1926; Crown Point, Lake County, August 5, 1926; Wabash River below Markle, Huntington County, August 29, 1926.

100. *Libellula pulchella* Drury. While collecting along "Old Canal," Noble County, July 5, 1926, a male of this species with a defective wing was noticed. E. B. Williamson watched the insect in flight for several minutes but could see no disadvantage arising from the defect. Upon capture about two-thirds of the right rear wing was found to be missing and the condition of the broken edges and veins indicated that the defect had existed from emergence. Crown Point, August 5, 1926; pond, two miles north of Poseyville, August 27, 1926.

104. *Plathemis lydia* Drury. Tippecanoe County, near Lafayette, May 26, 1925; "Old Canal," Noble County, July 5, 1926.

106. *Nannothemis bella* Uhler. Fourteen males and seven females of this rare species were taken at Lane Lake, Lagrange County, July 18, 1926.

114. *Sympetrum vicinum* Hagen. Tile yard pond, Monroe, Adams County, September 15, 1925; Wabash River below Markle, Huntington County, August 29, 1926.

115. *Pachydiplax longipennis* Burmeister. Swamp, near Cowan, Delaware County, July 11, 1926.

118. *Celithemis elisa* Hagen. Associated with *Celithemis eponina*, along the edge of a small lake, Crown Point, Lake County, August 5, 1926.

119. *Celithemis eponina* Drury. See note under 118, *Celithemis elisa.*

121. *Panatala flavescens* Fabricius. Posey County, August, 1925, (R. W. Montgomery); Eel River, southeast of Churubusco, Allen County, August 22, 1926.

125. *Tramea onusta* Hagen. A recent study of the Indiana specimens of Trameas in the Williamson Collection revealed the fact that two specimens of *onusta* had been assigned to *carolina* and recorded as that species. The specimens were collected at Vanemon Swamp, Wells County, May 30, 1913, and June 17, 1923. Correspondents who have received Trameas from the Williamson Collection should check this

material for the determination of these two species. Corrections may involve changes in the geographical and seasonal ranges given for the two species in Indiana.

The addition of this species to the list from Vanemon Swamp brings the total number of species known from that locality to 35. This swamp, which has been studied by E. B. Williamson for over 25 years as a representative woodland swamp habitat of northern Indiana, was visited several times during the season of 1926 and the following note for June 16 may be taken as typical. Dragonflies were comparatively rare; *Anax junius* was common, a few individuals of each of *Libellula pulchella, Pachydiplax longipennis, Ischnura posita,* and *Ischnura verticalis* were seen. *Aeshna mutata,* represented by a single individual, was present for the second time in 12 years. Lestes were numerous, but no *eurinus* were found. Enallagmas, Trameas, and *Libellula quadrimaculata* were absent. The water was deep. Spatterdock was unusually large and the clumps were spreading. Several clumps of *Scirpus lacustrius* have apparently become established in the northwestern part of the swamp, where a few clumps of Sparganium have also become established, (25 years ago almost the entire swamp was covered with Sparganium). The swamp smartweed was less vigorous and of lesser quantity than during recent years. The painted turtle was present in conspicuous numbers for the first time in many years.

INSECTS OF INDIANA FOR 1926.

J. J. DAVIS,[1] Purdue University.

As outlined in the last issue of the Proceedings of the Indiana Academy of Science, it is planned to submit each year a summary of the important insect problems as a basis for future work on insect predictions as well as for record.

Weather Conditions. The absence of an insect is usually due to unfavorable conditions for the natural enemies which normally hold it in check or, as in the case of such insects as the corn ear worm which is not as noticeably restricted by parasites, to weather or cropping conditions which are unfavorable to the insect directly.

Mild weather prevailed in February and early March. However, the latter part of March and during April the temperatures were abnormally low, being the coldest early spring season Indiana had experienced in 40 years. A raise to slightly above normal occurred by the last of May and continued above normal the remainder of the season. The cold weather of March and April delayed insect activity noticeably. Precipitation was approximately normal or below normal until August, when excessive rains occurred throughout the months of August, September and October, much in excess of normal. See table 1 and figures 1 and 2.

CEREAL AND FORAGE INSECTS.

Grasshoppers (*Melanoplus femur rubrum* De G. and *M. differentialis* Thos.) were more general and destructive than in 1925. Possibly less trouble than the year before in the extreme south end. They were damaging peppermint at Mishawaka in the north end of the state June 13. During July and August an increasing number of inquiries were received from the northern two-thirds of the state, the insects damaging clover, alfalfa, various flowers such as dahlia, and vegetable crops in general. They continued to give trouble until after the middle of September.

White grubs (*Lachnosterna* spp.). The adult May beetles were unusually abundant in the northern half of Indiana, especially in the northwestern quarter. Complete defoliation of timber trees was reported from Winamac, Rochester and other points.

Hessian fly (*Phytophaga destructor* Say). As shown in the report for 1925, the flies laid eggs up to the fly-free date but the unusually cold weather in October killed the eggs and small larvae so that the only infestations carried over were those of eggs laid a week or ten days before the fly-free date. The flies were first observed ovipositing at Lafayette May 3. The unusually wet weather the past fall permitted but little wheat to be sown before the fly-free date and there

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[1] The writer is indebted to H. F. Dietz, B. A. Porter, and C. R. Cleveland for records.

"Proc. Ind. Acad. Sci., vol. 36, 1926 (1927)."

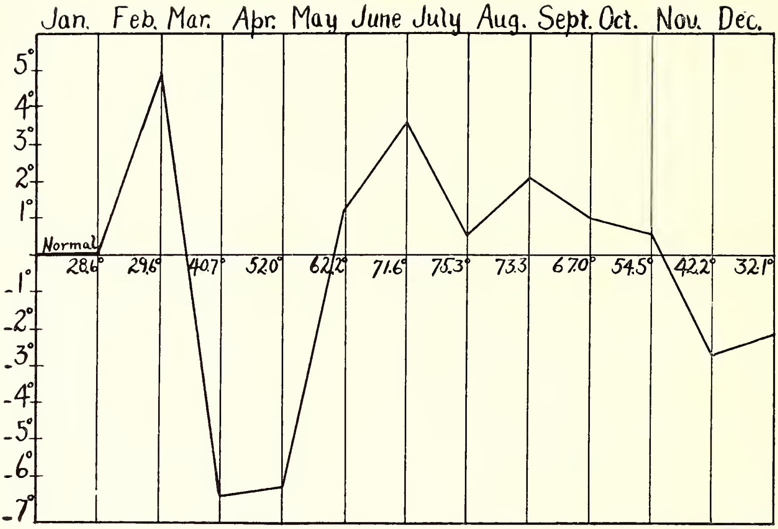

Fig. 1. Departures from normal temperature in Indiana for the year 1926, based on data in Climatological Data, issued monthly by the U. S. Weather Bureau.

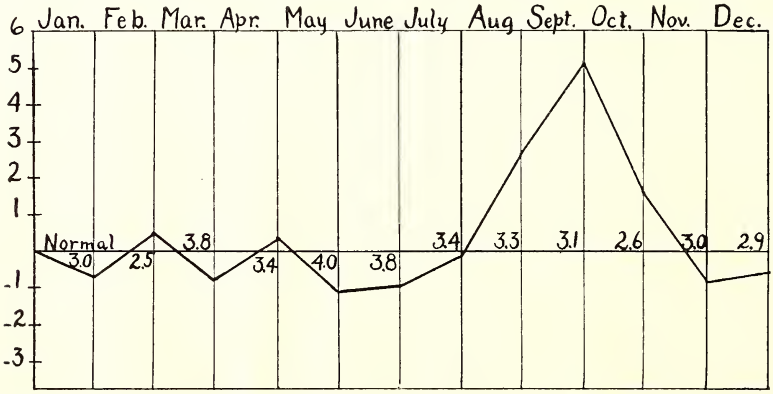

Fig. 2. Departures from normal precipitation in Indiana for the year 1926, based on data in Climatological Data, issued monthly by the U. S. Weather Bureau.

is comparatively little fly in the regularly sown wheat. However, the same wet conditions which prevented wheat sowing was the cause of an excessive amount of early volunteer wheat which, at the present time, is heavily infested. This may result in a heavy spring infestation of fly in 1927.

Chinch bug (*Blissus leucopterus* Say). Showed up spottedly in Indiana in 1926. The first report to reach us was July 19, unusually late. Reports of damage came from Union City, Kentland, Portland, Montmorenci and Linton. Wet conditions during the latter part of the season were unfavorable and there is little likelihood of trouble from this insect in 1927.

TABLE I. Comparative Monthly Weather Data for Indiana

MONTH	Temperature		Precipitation		Number of Days		
	State Mean	Departure from Normal	State Average	Departure from Normal	Clear	Partly Cloudy	Cloudy
	°F.	°F.	Ins.	Ins.			
Normal	28.6	4.6	3.05	1.21	10	7	14
January, 1926	28.6	0.0	2.26	−0.79	10	6	15
Normal	29.6	4.1	2.54	1.19	9	7	12
February, 1926	34.5	+4.9	2.85	+0.31	6	7	15
Normal	40.7	3.9	3.86	1.54	10	8	13
March, 1926	34.3	−6.4	3.05	−0.81	8	8	15
Normal	52.0	2.1	3.49	1.23	11	9	10
April, 1926	45.8	−6.2	3.75	+0.26	13	7	10
Normal	62.2	2.8	4.01	1.07	12	10	9
May, 1926	63.4	+1.2	2.89	−1.12	16	10	5
Normal	71.6	2.2	3.83	0.96	13	10	7
June, 1926	67.5	−4.1	2.93	−0.90	15	10	5
Normal	75.3	1.7	3.40	1.05	15	11	5
July, 1926	75.7	+0.4	3.30	−0.10	17	10	4
Normal	73.3	1.7	3.31	1.04	15	10	6
August, 1926	75.4	+2.1	6.16	+2.85	11	11	9
Normal	67.0	2.6	3.12	1.02	15	8	7
September, 1926	68.0	+1.0	8.17	+5.05	8	9	13
Normal	54.5	2.9	2.69	1.16	15	7	9
October, 1926	55.0	+0.5	4.32	+1.63	9	11	11
Normal	42.2	2.4	3.09	1.19	12	7	11
November, 1926	39.5	−2.7	2.10	−0.99	8	6	16
Normal	32.1	3.9	2.90	1.03	9	7	15
December, 1926	29.9	−2.2	1.96	−0.74	7	5	19

The common army worm (*Cirphis unipuncta* Haw.) was unusually abundant. The outbreak was anticipated by an unusual abundance of moths at lights and at apricot flowers the latter part of April in southern Indiana. The first reports of abundance of the worms came from Poseyville in the southwestern corner of the state May 31. Following the report from Posey County, reports were received from the following counties in order named: Jackson, Daviess, Knox, Greene, Sullivan, Benton, Rush, Warren, White, Pike, Marion, Hancock, Johnson, Montgomery, Tippecanoe, Carroll, Boone and Shelby. The peak of abundance was the first half of June and the last report was received June 21. Beginning on June 19 reports of an abundance of the white parasite cocoons were received, indicating an abundance of parasites. Crops damaged included timothy, oats, wheat and corn.

Cutworms (*Noctuidae*) were unusually abundant the past season. Reports began coming in early in May and continued till the first of July, which was unusually late. A six-acre field of onions at Angola was damaged May 12, but complete destruction, as experienced the previous year, was prevented by using the poison bran bait. Pansies were damaged May 18 at Richmond. Tomatoes and cabbages were damaged in many localities, as was also corn. A severe infestation of cutworms in peppermint was reported from South Bend June 9. All of the authentic reports received were from the northern half of the state and were general.

The common stalk borer (*Papaipema nitela* Guen.) was an outstanding pest the past season and was more abundant and more general than in 1925. The first report came from Valparaiso June 3, where the borer was destroying tomatoes. Reports continued to be received up to July 26. Following this initial report, records of abundance and destructiveness were received from the following counties in order of receipt: Porter, Blackford, Vanderburgh, Marion, Dearborn, Hendricks, Morgan, Clinton, Fayette, Rush, Owen, Boone, Tippecanoe, Randolph, Montgomery, Warren, Adams, Union, Vigo, Delaware, Johnson, Sullivan, Lawrence, Fountain, Howard, Jefferson, Madison, Grant, Marshall, Lake, Adams, Steuben, White and Decatur. Corn was the crop most often reported as being attacked and tomatoes next. Also reported damaging potatoes, onions, beans, hollyhocks, and dahlia.

Billbugs (*Sphenophorus* spp.) damaged corn at Jeffersonville in the extreme southern part of the state June 26, at Frankfort in central Indiana July 9 and larvae were abundant in timothy at Winamac in the north central part of the state July 19. Apparently normally abundant.

Wireworms (*Elateridae*) were reported early in the season from Brookville infesting sprouting potatoes and from Steuben County where they practically destroyed an eight-acre field of onions. By June 26 several reports were received from northeastern Indiana indicating unusual abundance and destructiveness to onions. Corn was damaged at Madison, Jeffersonville, Indianapolis, Spiceland, North Manchester and Decatur, the last reports coming to us July 13.

Corn ear worm (*Heliothis obsoleta* Fab.) damaged both field and sweet corn in central and southern Indiana during August and September but was not as destructive as in 1925.

European corn borer (*Pyrausta nubilalis* Hbn.) entered the state in 1926, lightly infesting the six northeastern counties, namely, Steuben, DeKalb, Allen, LaGrange, Noble and Whitley. Although reports have been made in the daily press from other sections of the state no authentic records are available. Dozens of the common smartweed borer (*P. ainslei*), which frequently go to pithy stemmed plants to pass the winter, were found in corn stalks and sent in as possible corn borers.

The corn leaf aphid (*Aphis maidis* Fitch) was abundant and apparently destructive to sorghum at Columbus, July 21, and to sugar cane at Aurora, August 3.

Corn seed maggot (*Hylemyia cilicrura* Rond.) was very destructive to corn the latter part of May in St. Joseph, Adams and Rush counties. At Lafayette 50 per cent of a commercial garden bean field was destroyed during early June.

Leather jacket larvae (*Tipulidae*) were reported abundant and injuring corn at Rushville, May 19.

Corn webworms (*Crambus caliginosellus* Clem.) were more abundant and destructive than for several years. The first report of injury to corn came to us May 31 from Salem in the southern part of the state. This report was followed by reports of damage to corn up to June 15 from many localities in the central part of the state.

The banded flea beetle (*Systena taeniata* Say) was destructive to various crops, especially to corn and cabbage, at Lafayette, Cambridge City, Rushville and Williamsport. These reports were received between June 18 and 25. Damage to corn was severe at Ambia June 28 and to soybean at Plymouth June 26.

The green bug (*Toxoptera graminum* Rond.) was abundant in Indiana for the first time in many years. It was reported from Anderson and Argos, July 18 and 19 respectively, and was apparently doing some damage to oats.

The wheat stem maggot (*Meromyza americana* Fitch) reported damaging wheat at Greenfield, June 28.

The green clover worm (*Plathypema scabra* Fab.) was abundant from August 25 to September 2, especially in the southern counties, but ranging northward to Pulaski County. It was destructive to clover, alfalfa, soybean and garden bean.

Leaf hoppers (*Jassidae*) accompanied a yellowing and leaf spot of hundreds of acres of alfalfa in northern Indiana, according to reports from members of the Purdue Soils and Crops Department. The heavy infestation of leaf hoppers apparently was more than a coincidence.

Clover root borer (*Hylastinus obscurus* Marsh.) caused considerable injury to red clover sod early in August in the vicinity of Lafayette.

Clover white grub (*Colaspis brunnea* Fab.) caused considerable damage to corn throughout central Indiana during June and early July. Reports included Rush, Wayne, Morgan, Warren and Montgomery counties. Greatest damage seems to be to corn planted on spring plowed red clover sod.

The clover leaf weevil (*Hypera punctata* Fab.) was not as abundant as usual. Some reports of injury to little red and sweet clovers were received from southern sections of the state. On May 26 reports of heavy infestations from north central Indiana were received.

VEGETABLE INSECTS.

The Mexican bean beetle (*Epilachna corrupta* Muls.) continued as a serious pest in the southeastern quarter of the state. New records for 1926 include Frankfort and Bluffton, the latter reported by C. C. Deam through H. F. Dietz.

Bean leaf beetle (*Cerotoma trifurcata* Forst.) was reported abundant and damaging bean foliage at Shoals May 14 and Petersburg June 16.

A species of Empoasca was reported damaging beans at Paoli June 28.

The potato flea beetle (*Epitrix cucumeris* Harr.) continues as an outstanding potato pest in many sections of the state.

Potato leafhopper (*Empoasea mali* Le B.) is an increasingly important insect of potato. Damage was reported as far south as Danville in 1926.

The common mole cricket (*Gryllotalpa hexadactyla* Perty) was reported damaging potato tubers at Morgantown July 26.

Cabbage and radish maggot (*Hylemyia brassicae* Bouché) was more abundant than usual in the northern half of the state. Reports of damage to cabbage and radish were received throughout the month of June from Bluffton, Elwood, Monticello, Tipton, Marion, Monterey, Modoc, Knightstown, South Bend, and Goshen. An unusual number of reports were received from central Indiana. The normal range is the northern quarter of the state.

Cabbage aphid (*Brevicoryne brassicae* L.) damaged cabbage at Lafayette and elsewhere during July.

The cabbage worm (*Pontia rapae* L.) was abundant and destructive throughout the state during June, July, and August.

Garden flea hopper (*Halticus citri* Ashm.) damaged tomatoes at Terre Haute during the first half of September.

Striped blister beetles (*Epicauta vitatta* Fab.) damaged tomatoes at Romney July 22. Black blister beetles (*E. pennsylvanica*) were damaging tomatoes at Pendleton July 22. During latter part of July and early August blister beetles were conspicuous and occasional reports were received up to September 9. Tomatoes, potatoes and flowering plants, especially aster, were the principal plants attacked. In one case a commercial planting of gladioli at LaGrange was seriously damaged. Preliminary experiments gave excellent control of blister beetles on potato with sodium fluosilicate applied as a dust.

Onion maggot (*Hylemyia antiqua* Meig.) was unusually abundant and destructive the past spring throughout the northern quarter of the state, especially in the northeastern counties. Reports of unusual serious damage came in between June 15 and 23 from Albion, Helmer, Kewanna, Knox, Larwill, Pleasant Lake, Shipshewana, Etna Green, and South Bend.

The squash vine borer (*Melittia satyriniformis* Hbn.) was common as usual. Reports were received from several localities in the central part of the state the latter part of July.

Asparagus beetle (*Crioceris asparagi* L.) did considerable damage in home gardens at Vincennes. The twelve-spotted asparagus beetle (*C. duodecimpunctata* L.) was observed in numbers at Lafayette for the first time.

The greenhouse centipede [*Scutigerella* (*Scolopendrella*) *immaculate* Newp.] is increasingly destructive in vegetable greenhouses where serious losses, especially to lettuce, occur.

The melon aphid (*Aphis gossypii* Glov.) began to appear in threatening numbers during June and early July in many sections but the action of the natural enemies checked what appeared to be an incipient outbreak.

The striped cucumber beetle (*Diabrotica vittata* Fab.) caused considerable loss, especially in central Indiana. It was apparently about normally abundant.

The false cabbage aphid (*Aphis pseudobrassicae* Davis) was abundant on turnip and radish in the northern half of the state during late June and early July.

FRUIT INSECTS

San Jose scale (*Aspidiotus perniciosus* Comst.) was less troublesome than for several years. In vigorous growing orchards where proper spraying has not been practiced the scale is a serious problem. According to Porter the winter mortality was 48.6 per cent as compared with 79 per cent the previous winter (1924-25), 57 per cent 1923-24, and 28 per cent 1922-23. In an old apple orchard in poor condition the winter mortality was 72 per cent. The first crawlers at Vincennes were noticed June 11, about 10 or 12 days later than 1925. The second brood crawlers appeared between July 25 and August 1, 13 to 20 days later than last year.

Apple scurfy scale (*Chionaspis furfura* Fitch) was reported as abundant and apparently destructive to apple throughout state. So far as data were obtainable this scale was abundant only in orchards unsprayed or poorly sprayed with the dormant spray. As abundant as last year and in many sections more so.

Apple aphids (*Aphis pomi* De B., *Anuraphis roseus* Bak., and *Rhopalosiphum prunifoliae* Fitch) were practically totally absent early in the season. This was apparently the result of the severe weather early in October, 1925, the cold weather coming before the embryos had made their revolution, which seems to be essential to protect the insect within the egg against severe cold. By the last of June the green apple aphis had become moderately abundant in some orchards.

The apple red bug (*Lygidea mendax* Reut.) was observed occasionally but never abundant.

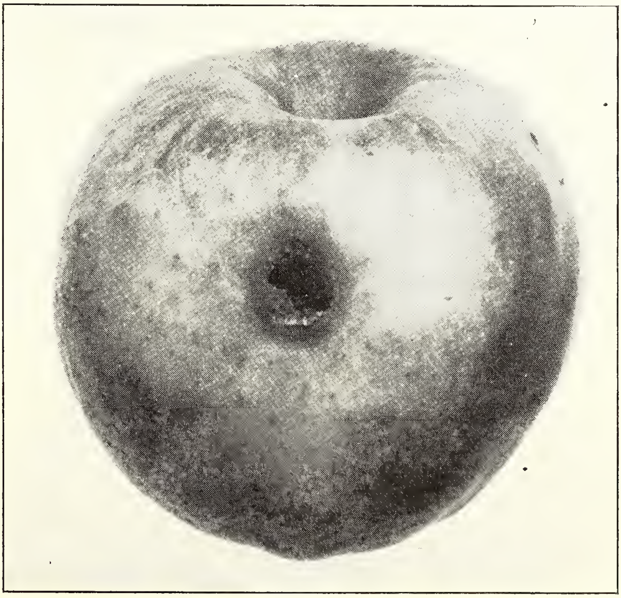

Fig. 3. External evidence of side infestation by codling moth larva. Slightly less than natural size.

Leaf hoppers (*Jassidae*, especially *Erythroneura obliqua* Say and var. *dorsalis* Gill.) became extremely abundant in August, in all apple orchards in southern Indiana. Foliage was badly damaged and fruit showed considerable specking as a result of deposits of excrement.

Codling moth (*Carpocapsa pomonella* L.) increased very materially the past season, resulting in great losses in some orchards and an increase of wormy apples (fig. 3) over last year in nearly every orchard in southern Indiana. The weather conditions were favorable for the insect last fall and again this spring and early summer. These favorable conditions, together with general trend of increasing abundance and the heavier infestations of 1925, have been largely responsible for the increasing seriousness of the codling moth situation.

Porter observed the first moths at Vincennes May 13. The first worms were leaving the fruit about June 19 and the first moths of the second brood July 2. The first eggs of the second brood hatched about July 10.

Even in well sprayed orchards there was considerable damage. In such cases but few of the larvae entered the fruit and matured but they entered the fruit a fraction of an inch before succumbing to the poison, thus marring the fruit. Such injuries are known to growers as "stings". (Figs. 4 and 5).

Apple tent caterpillar (*Malacosma americana* Fab.) A recently hatched infestation was reported May 8 from Walkerton in St. Joseph County. Another infestation was reported from Winamac.

Flat-headed borer (*Chrysobothris femorata* Fab.) was normally abundant throughout the state.

The unicorn caterpillar (*Schizura unicornis* S. & A.) defoliated young apple orchards at Greencastle previous to July 15.

Red-humped caterpillar (*Schizura concinna* S. & A.) defoliated apple at Spencerville, in Dekalb County, previous to September 15. Porter reports them as more abundant than usual in the vicinity of Vincennes. In young apple orchards with little or no spray they were especially common.

Yellow-necked apple caterpillar (*Datana ministra* Drury) was more abundant than usual. Defoliated a considerable number of two-year old apple trees near Indianapolis early in August. Porter reports abundance near Vincennes in young apple orchards which have received little or no spray.

Apple fruit chafer (*Metachroma interruptum* Say) not abundant and no commercial damage. W. P. Flint observed that they were noticeably repelled by arsenicals in Illinois. In one orchard where one block of trees were sprayed only with oils and the remaining trees with an arsenical, there was no commercial damage to the trees sprayed with arsenate of lead and noticeable damage to those sprayed with oil.

Apple flea weevil (*Orchestes pallicornis* Say) was less abundant than in 1925 and there was no commercial damage.

Lesser apple worm (*Laspeyresia prunivora* Walsh) was reported as common and destructive during September from several localities in central Indiana but in general was not very conspicuous or destructive, at least not in southern Indiana.

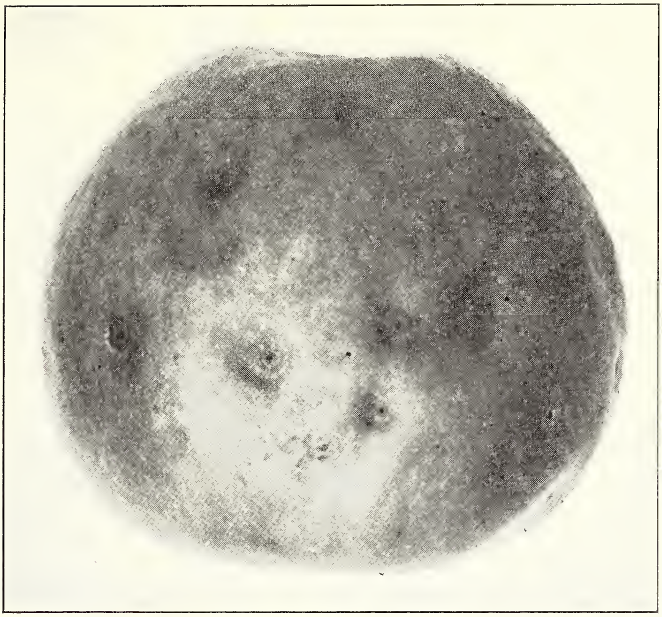

Fig. 4. So-called "stings," where codling moth larvae died soon after entering fruit, probably death resulting from poison eaten on entering. See figure 5.

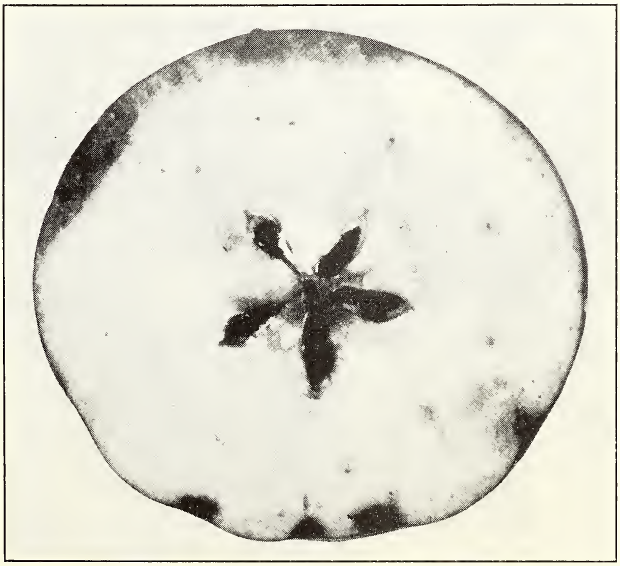

Fig. 5. Same apple as shown in figure 4 cross sectioned to show the internal evidence of codling moth larvae "stings."

The red-banded leaf-roller (*Eulia velutinana* Walk.) was not abundant according to our observations the past season.

Bagworms (*Thyridopteryx ephemeraeformis* Haw.) were prevalent in southern Indiana as usual and cocoons were reported as common in orchards. The recently hatched young were first observed June 30 at Terre Haute. This insect was very abundant on shade trees and evergreens in southern Indiana and also was reported defoliating apple trees where little or no spray was applied. Reports were unusually numerous during August.

Plum curculio (*Conotrachelus nenuphar* Hbst.) more or less scattered and in some sections injurious but not more than normally abundant.

Peach tree borer (*Anarsia lineatella* Zell.). Weather conditions were unfavorable last fall for most effective results from the paradichlorobenzene treatment. The situation is not serious however, although many reports were received early in the summer relative to borer abundance.

According to Porter the peak of emergence of the adults, at Vincennes, occurred the last week in August. Emergence continued until about September 10, when it appeared to be practically completed.

Lesser peach tree borer (*Synanthedon pictipes* G. & R.) was common but no worse than in 1925 and probably not quite so bad. Reports of damage were received from all sections of the state.

Shot hole borer (*Eccoptogaster rugulosus* Ratz.) was not as conspicuous as during the past two years. There were, however, many reports of killing of peach and cherry trees from the southern half of the state and as far north as Portland.

Tarnished plant bug (*Lygus pratensis* L.), responsible for considerable damage to peaches the past few seasons in southern Indiana, was unusually scarce early in the spring and as a result the "cat-facing" of peaches was not severe. This insect was reported from Walkerton, May 7, as responsible for wilting of shoots of currants.

Cotton caterpillar moth (*Alabama argillacea* Hbn.) was more abundant and more destructive than for many years, although a few cases of injury have been received every year for three or four years. This year reports came from the following counties, in the order named; Clark, Knox, Kosciusko, Putnam, Montgomery, Lawrence, Jasper, LaPorte, Howard, Wabash, Allen, Gibson, Washington, Owen, and Tipton. First reports received September 15 and continued into October. However, Porter observed them September 1 at Vincennes, just as the Elberta peach harvest was nearly completed, and we noticed them in central Indiana, abundant at lights, September 7. According to all records these moths have never reached Indiana until after the harvest of Hale and Elberta peaches, the principal varieties grown and the damage has been largely to the late peaches and to a lesser extent to grapes and apple.

Rose chafer (*Macrodactylus subspinosus* Fab.) first reported as destructive to fruit (fig. 6) May 29 at Petersburg. Subsequently ap-

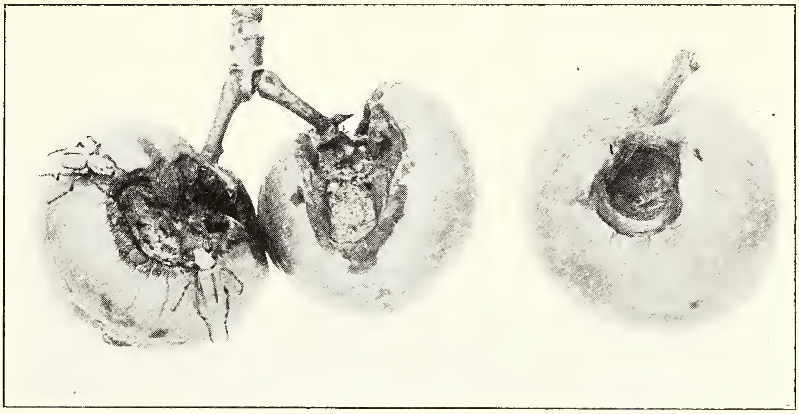

Fig. 6. The rose beetle (*Macrodactylus subspinosus* Fab.) has been a destructive pest of fruits, foliage and young corn in many sections of Indiana for several years. They are also poisonous to young chicks which eat them freely when given an opportunity.

preciably destructive at Hazleton June 3, Princeton June 5, Terre Haute June 7. At Terre Haute the beetle was especially destructive to peach.

Imported currant worm (*Pteronidea ribesi* Scop.) was noticeably injurious in Indianapolis May 18. Dietz observed hatching larvae at Indianapolis early in May.

The currant aphid (*Myzus ribis* L.) was common as usual throughout the state.

The Houghton gooseberry aphid (*Aphis houghtonensis* Troop) was destructive to gooseberry at Culver according to reports received June 21. Apparently less destructive than usual.

Pear and cherry slug (*Caliroa cerasi* L.) defoliated pear at Elkhart according to a report received September 14. In general less abundant than for several years.

Rhinoceros beetle (*Dynastes tityrus* L.) was received from Salem July 19 with the report that it was damaging ripening peaches.

The eight-spotted forester (*Apypia octomaculata* Fab.). Moths observed by F. N. Wallace at Indianapolis May 16.

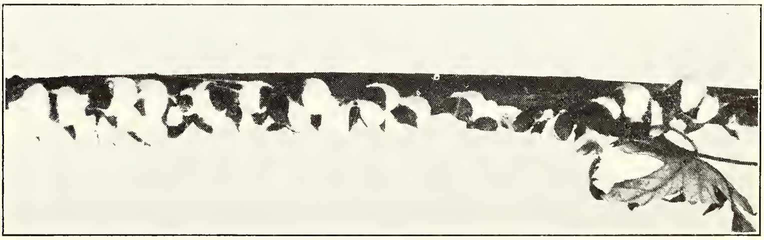

Fig. 7. The cottony maple scale (*Pulvinaria vitis L.*) on branch of maple. Each of these conspicuous cottony masses contain 2000 or more eggs. A serious pest throughout the northern half of Indiana.

The grape leaf-hopper (*Erythroneura cornes* Say) common throughout central Indiana.

Strawberry leaf-roller (*Ancylis comptana* Froehl.) was reported quite destructive to strawberry at Culver, June 21.

SHADE TREE AND SHRUB INSECTS

Cottony maple scale (*Pulvinaria vitis* L.) (fig. 7) was more abundant in some sections of the northern half of Indiana than usual. For example, it appeared at Lafayette and vicinity in destructive numbers for the first time according to our observations, dating back to 1911. It seems to be more abundant in central Indiana and probably somewhat less abundant in the northern counties. Reports began coming in May 28 and during the season over 100 letters of inquiry were received. The counties represented by these inquiries were as follows: Adams, Allen, Blackford, Boone, Carroll, Decatur, Delaware, Elkhart, Fountain, Grant, Hamilton, Hendricks, Henry, Howard, Huntington, Jay, Madison, Marion, Miami, Newton, Pulaski, Randolph, Rush, Shelby, Starke, Steuben, Tippecanoe, Vermillion, Wayne, Wells and White. The eggs began hatching at Lafayette June 26.

Elm scurfy scale (*Chionaspis americana* Johns.) continued as a pest of young elms in central and northern Indiana.

Oyster shell scale (*Lepidosaphes ulmi* L.). The light brown form began hatching at Indianapolis May 15 according to Dietz. This was somewhat later than usual and nearly three weeks later than 1925. The first young of the form common on lilac were observed at Lafayette June 26. This insect is normally abundant. Reported abundant on apple in a few instances but according to our observations only where regular dormant sprays are omitted.

Snowball aphid (*Anuraphis viburnicula* Gill.) reported as very troublesome in some localities in central Indiana early in May.

Elm cockscomb gall (*Colopha ulmicola* Fitch) reported abundant in several localities in central and north central Indiana.

Walnut caterpillar (*Datana integerrima* G. & R.) was unusually abundant in the vicinity of Vincennes, according to Porter, completely defoliating many walnut trees. It was normally abundant in central Indiana. We received reports of injury from the following counties; St. Joseph, Grant, Hamilton, Clay, Madison, Miami, Howard and Johnson.

Catalpa sphinx caterpillar (*Ceratomia catalpae* Boisd.) much less abundant than usual. Many trees came through the season with most of their foliage which was unusual. Reports of abundance were received from Howard, Orange and Grant counties.

The hickory horned devil (*Citheronia regalis* Fab.) was unusually abundant and many letters, accompanied by specimens were received between August 24 and September 17. Localities included Martinsville, Lafayette, Rushville, Elnora, Burney, Waveland, and Greensburg, all from central or southern Indiana.

White marked tussock moth caterpillar (*Hemerocampa leucostigma* S. & A.) was common in central Indiana and judging from the cocoons and egg masses at present they will be exceedingly abundant in 1927. A few instances of their abundance on apple were reported but only in poorly sprayed orchards.

The locust leaf-miner (*Chalepus dorsalis* Thunb.) was destructive to honey locust at Richmond early in August.

The gouty vein gall (*Dasyneura communis* Felt) was received from Edinburg June 6. This gall was sent to us in 1925 for the first time, that record coming from southern Indiana.

The maple bladder gall (*Phyllocoptes quadripes* Shim.) was reported from several places in central Indiana during June and July.

The large linden aphid (*Longistigma longistigma* Wils.) (fig. 8) is common every year and is sometimes sufficiently abundant to be annoying. The same is true of the common species in willow (*Melanoxantherium salicti* Harr.)

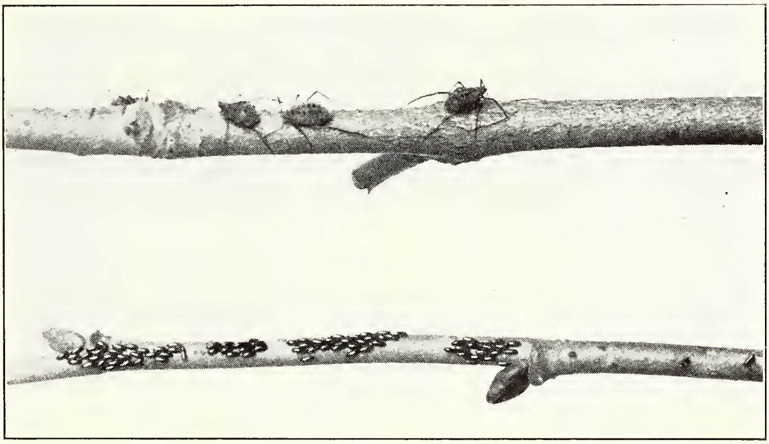

Fig. 8. *Longistigma longistigma* Wils. on linden. This is the largest known species of aphid. Below are shown the jet black eggs as they are laid on linden. Natural size.

FLOWER GARDEN AND GREENHOUSE INSECTS

Onion thrips (*Thrips tabaci* L.) was a very troublesome pest of chrysanthemum during May, according to Dietz. Feverfew and carnations also suffered from the attacks of this insect.

Greenhouse thrips (*Heliothrips haemorrhoidalis* Boché) was reported by Dietz as a troublesome pest of chrysanthemum in greenhouses.

Verbena leaf miner (*Agromyza jucunda* V. d. Wulp) abundant throughout central Indiana latter half of July.

The caterpillar of the painted lady butterfly (*Vanessa cardui* L.) was abundant in central Indiana on Canada thistle. Occasionally they damaged hollyhocks. The insect continued more or less conspicuous from July to September.

Violet sawfly (*Emphytus canadensis* Kirby) damaged pansies at Ft. Wayne the latter part of June.

Rose midge (*Dasyneura rhodophaga* Coq.) was noticeably abundant in two greenhouses at Newcastle during the spring months according to Dietz.

Chrysanthemum gall midge (*Diarthronomyia hypogaea* Coq.). Dietz reports light infestations in central and northern Indiana and a heavy infestation at Kokomo where no attempt was made to control.

The method of shearing off the tops of the stock plants to the ground line or slightly below, keeping the plants rather dry until growth starts again, has proven to be an effective control of this insect if all stock plants are thus treated, according to Dietz. Better plants than usual have been produced by this method.

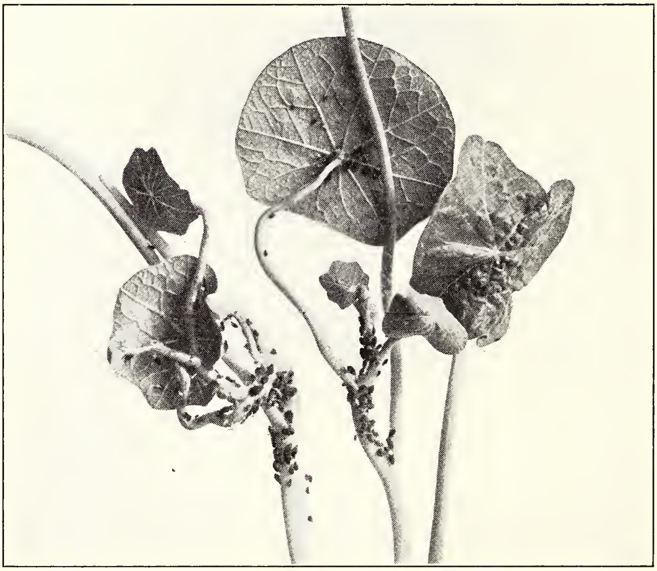

Fig. 9. The black nasturtium aphid (*Aphis rumius L.*) is present every year and causes a deformity of stems and foliage.

Iris root borer (*Macronoctua onusta* Grt.) was probably more abundant than in 1925. The eggs began hatching at Indianapolis, according to Dietz, May 2 and continued to hatch on warm days up to May 18.

Greenhouse leaf-tyer (*Phlyctaenia rubigalis* Gn.) was common in all greenhouses, being especially common on cineraria, feverfew, Calceolaria, chrysanthemum, forgetmenot, snapdragon and geranium. Damage to celery at Goshen was reported August 13.

Aphids were less abundant than usual. Common species observed, include black nasturtium aphid (*Aphis rumicis* L.) on nasturtium (fig. 9) and poppy; also aphids on rose and sweet pea.

Red spider (*Tetranychus telarium* L.). Dietz reported heavy infestations in greenhouses. Especially common on roses, carnations, gladioli and sweet pea. Abundance in part due to cloudy weather from October till May which interfered with proper syringing of plants.

A mite, probably *Rhizoglyphus hyacinthi* Boisd. was destructive to gladioli at Columbus during July.

The cyclamen mite (*Tarsonemus pallidus* Banks) was destructive in a greenhouse at Marion in March.

STORED PRODUCTS

Grain weevils were abundant throughout the state the past fall. According to our observations in the vicinity of Lafayette and from specimens sent to us, the species which was unusually numerous was the foreign grain weevil (*Cathartus advena* Walt.). Because of the excessive moisture when grain was threshed and the continued high humidity, grain has shown a decided tendency to mold and offered conditions ideal for this species of grain beetle which lives primarily on mold. These beetles apparently have been largely responsible for the heating of grain, which has been so commonly reported the past fall.

ANIMAL AND HUMAN PESTS

The ox warbles (*Hypoderma bovis* DeG. and *H. lineata* DeV.) were less abundant than usual. *H. bovis* seems to be the prevalent species in the northern half of the state.

Mosquitoes (*Culicidae*) appeared in a veritable plague throughout central Indiana beginning September 18 and lasting a week. In the southern end of the state mosquitoes were reported abundant beginning a month or more earlier.

Fleas (*Ctenocephalus canis* Curt.) were very abundant and annoying throughout the state as evident by the numerous letters of inquiry. During June they were especially noticeable in dwellings and hog houses. In September they were unusually abundant, especially in dwellings in the southern two-thirds of the state.

Saddle-back caterpillar (*Sibine stimulea* Clem.) (fig. 10) was re-

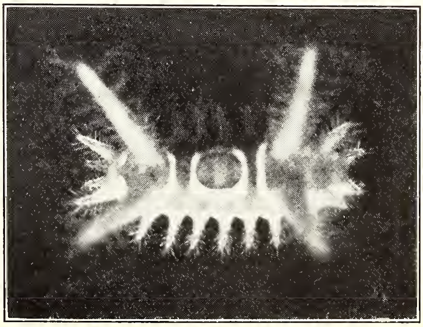

Fig. 10. The saddle-back caterpillar (*Sibine stimulea* Clem.) bears "stingings" hairs which cause an irritation and sometimes a rash when they puncture the skin. About one and one half times natural size.

ported as annoying, as described in our last year's records, from Greencastle, Martinsville, and Ft. Wayne between August 28 and September 7.

HOUSEHOLD INSECTS

Cockroaches continue to be abundant in dwellings, stores, cream stations and packing sheds, in spite of the simple and effective sodium fluoride treatment.

Ants were numerous as usual in lawns and gardens and especially as pests in dwellings.

MISCELLANEOUS INSECTS

Termites or white ants (*Reticulitermes flavipes* Koll.) continue as very serious pests of woodwork in buildings. It is most serious in southern half or two-thirds of the state but one report of damage came from Kendallville in the northeastern corner of the state.

Powder post beetle (*Lyctus* sp.) was reported as damaging woodwork more the past year than ever before, most of the reports coming from central and southern Indiana. Damage included joists and other timbers of buildings, chairs and rough hickory furniture.

Tobacco worms (*Protoparce quinquemaculata* Haw.) were abundant at Milltown the latter part of July.

SOME HABITS OF LIMAX MAXIMUS

CLEM O. THOMPSON, Ball Teachers College.

One evening in early October of 1917, while the writer was an instructor in biology in the Salem, Indiana, High School, his attention was called by Mr. E. D. Williams to the position of two slugs. The tail of the front slug was touching the head of the rear slug immediately between the protruding tentacles. They had been following each other for some time in the position illustrated in the accompanying pen sketch. In order to take a picture of them, a smooth pine board was placed in their path. They crawled upon the board still maintaining the same position. It was so late in the evening, however, that a "snap shot" could not be taken and a timed exposure was ruined due to their movements.

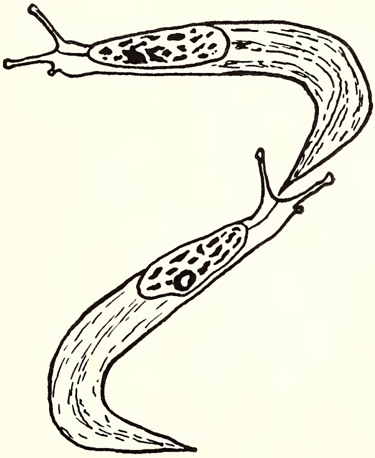

Fig. 1. Limax maximus L. (?) as observed in their trailing position.

The writer then separated them a little distance. In a very short time they were again as illustrated. Time and again they were separated, the distance being increased each time. Each time they resumed their former position. This process of separating them and of their resuming the trailing continued for about a half hour. They were then placed about two feet from each other. This time each drew up into a little ball and no amount of molestation could induce them to move. Whether this failure was due to the distance or to their being exhausted is not known.

Observations were made until quite late at night but no slugs were found to be in this position. The next evening, quite late, two were seen in the position, in whch they were seen on the former evening.

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Observations were continued each evening until winter but no further recurrence of the habit was noticed. In October of the following year, Mr. Williams reported seeing two slugs in the same position. He separated them a few inches and they remained apart.

There is some question in regard to the identity of the species, hence the question mark. The writer had no key nor was one available in the local library. When fully elongated they were about four and one-half inches long. Some specimens were covered with large brownish-black spots, others were a light gray with faint stripes of dark running lengthwise. All were distinctly keeled.

RAISING FLEAS FOR LABORATORY PURPOSES.

S. A. RIFENBURGH, Purdue University.

Fleas are so different from other insects that taxonomists have placed them in a separate order, Siphonaptera. Yet they are very common, and are to be found on practically every dog and cat, on many other mammals, on birds, and at least once they have been found on a reptile. They are instrumental in the dissemination of several diseases, among which may be mentioned bubonic plague, kala azar, tapeworm, and possibly leprosy. Thus, it is clear that every course in Zoology, Entomology, or Parasitology should include much about them. However, there are few such courses in which the students are given access in the laboratory to all the stages in their life history. Therefore, I believe that this paper should prove of interest to the members of the Indiana Academy of Science and others who are engaged in teaching these subjects.

In their life history, fleas pass through a complete metamorphosis similar to that of many other insects. The adults, male and female, live on their host a part or all of the time, according to the species. They feed upon blood once or twice a day. The small pearly eggs of which several may be laid in a day by one female, are not attached but are dropped and fall off the host wherever it may be. Thus it comes about, that many eggs fall upon the bedding and litter where the animal sleeps. In three days or more, according to temperature and humidity, these eggs hatch out into tiny white maggots. These feed upon the feces of their parents, feces of the host and other organic matter until they become about one-fifth of an inch in length. The time spent in the larval stage may vary from a week to months according to temperature, humidity and food. Meanwhile, they molt two or three times. At the end of the larval period, a cocoon is usually formed of silk and entangled objects, inside of which the pupa stage is spent. In a week or more the adult emerges.

For laboratory use, the adults can best be obtained by removing them from a cat or dog. This may be done by simply picking them out of the fur with tweezers, or the entire animal may be placed inside of an etherizing jar and both host and parasites etherized. Afterward, the fleas may be obtained by rubbing the fur and recovering them as they fall on a sheet of paper.

The eggs may be obtained from an infested cat or dog. Such an animal is confined in a small cage or box on the floor of which a paper has been spread. At the end of several hours or a day, the eggs are shaken off the paper into a suitable container.

The best way of obtaining larvae and pupae is by raising them from eggs collected as described above. A glass dish such as a crystallizing dish, about two and one-half inches high by four or five inches

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in diameter makes a good culture jar. The eggs are shaken into such a culture jar and a teaspoonful of finely chopped rat (or other) feces added and the dish covered with a piece of glass. One-fourth of a four-inch filter paper is folded until it is about four plies in thickness. This is placed between the edge of the culture jar and the cover. This filter paper is then connected to a container of water by means of a wick which is made by twisting together a few strands of woolen yarn or strands from a raveled lamp wick. The filter paper thus serves two purposes; first, it holds up the cover, allowing an exchange of air, and second, it supplies moisture. One must be careful not to allow any of the filter paper to hang down into the culture jar, as water might drip from it and drown some of the fleas. It is best to elevate the culture above the source of the water supply. The culture should not be in direct light—I usually set the culture jar inside of a cylinder of dark paper.

In a properly prepared culture at room temperature, larvae appear in about three days, pupae a week or ten days later and adults in another week or two.

AGGLUTININ PRODUCTION: FREQUENCY OF INJECTIONS CONSTANT, DOSAGE AND TOTAL AMOUNT INJECTED VARIED.

CHARLES A. BEHRENS, Purdue University.

In a previous paper[1] entitled "Agglutinin Production. Frequency of Injections Varied, Dosage and Total Amount Injected Constant", it was demonstrated that small doses of a foreign protein injected not too frequently over a short period of time produces agglutinins of a higher titre than similar amounts of the antigen extended over a long period of time. It will be recalled that the above mentioned procedure, is quite the opposite of that used in daily practice both in vaccinating man and lower animals against disease.

Animals, therefore, that are injected daily with 1 cc. for ten days with a typhoid vaccine develop agglutinins of a higher titre than if they were inoculated with the same dose hourly, once or twice or even thrice weekly.

These results suggested the experiment in which the converse is taken up, namely, that of injecting animals with amounts varying from a very small (0.1 cc.) to a relatively large dose (10 cc.), and consequently the total amount inoculated into each animal will likewise vary from a small (1 cc.) to a large amount (100 cc.) over a period of ten days.

These results then will indicate whether or not high titre production depends upon the amount of antigen injected at one time and its tenfold total amount, or upon the frequency of stimulation of the body cells of the animal by inoculation of small amounts of the foreign protein.

Since this was a comparative experiment the antigen used in it was similar to the one used in the previous tests. It contained one billion typhoid bacilli which were killed by heating to 58° C. for one hour. The injections were all made intravenously at daily intervals. The doses of antigen varied from 0.1 cc. to 10 cc. which were constant for each set of animals inoculated throughout the experiment. Consequently it will be noted that some animals received as high as 100 cc. of the antigen while others were inoculated with a total amount of only 1 cc.

A pair of rabbits (I and II, see Table) were injected each with 0.1 cc. for ten days, receiving a total amount of 1 cc. of the typhoid vaccine. A second set of animals (III and IV) were inoculated with 1 cc. for ten days, or an amount totaling 10 cc. While a third series of a pair of rabbits (V and VI) were vaccinated for ten days with a dose of 10 cc., receiving in all 100 cc. of the antigen. These rabbits

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[1] Proc. Ind. Acad. Sci. 34: 259-260, 1926.

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were bled ten days after the last injection was made and the titres of the agglutinins in their sera were determined macroscopically.

It will be observed from the data contained in the table that rabbits I and II, which received only 0.1 cc. daily for ten days, or a total of 1 cc., developed agglutinins with titres 1:5000 and 1:8500 respectively, an average of 1:6750. The highest titres, those of 1:8500 and 1:10,000, an average of 1:9250, resulted when rabbits (III and IV) were inoculated with 1 cc. daily for ten days, thus receiving a total of 10 cc. of the vaccine, while the lowest titres 1:5000 and 1:4000, respectively, developed in rabbits (V and VI), or an average of 1:4500, which received daily injections of 10 cc. each or a final amount of 100 cc. of the antigen.

Upon further observation of the results included in the table, nothing especially striking is noted relative to the weights and the physical condition of the animals. There is, though, an indication as was rather remarkedly shown in a previous paper[1] that when the animals are not in good physical condition as observed principally by their weights and appearances, that there is usually also a poor degree of agglutinin developed, whereas, good physical condition makes for high antibody production. After all, this is, of course, what one would expect since some of the body cells produce these antibodies and consequently, if the animal is not fit and the cells are in a "low tone", nothing much can be expected of them.

Rabbits VI, V, and I which yielded sera with the lowest titres (1:4500, 1:5000, and 1:5000, respectively) also showed a poorer physical condition accompanied by a greater loss of weights (290, 220, and 230 grams respectively) than the other rabbits did with one notable exception. Although rabbit III, which also lost weight (240 grams) which was about as much as was lost by the animals (VI, V, I) just mentioned, produced a serum of a high titre 1:8500.

These results indicate that an agglutinin serum of a high titre can be developed in rabbits in good physical condition by successive daily injections of small doses (1 cc. and even as small as 0.1 cc.) of a bacterial protein. They further suggest the practicability of this method not only when vaccinating lower animals, but humans as well, in cases where the individuals are inoculated with bacterial antigen (bacterines).

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[1] Proc. Ind. Acad. Sci. 34: 259-260, 1926.

TABLE I. Showing the Agglutinin Titre, Weights and Physical Condition of Rabbits Injected * with Different Doses and Total Amounts at Similar Intervals.†

Number of Rabbit	Dose	Total Amount	Titre	Average Titre	WEIGHTS IN GRAMS				Physical Condition	Remarks
					Before Injected	After Injected	Loss	Gain		
I	0.1 cc	1 cc	1:5000	1:6750	1700	1470	230	....	Fair	Good condition two weeks later
II	0.1 cc	1 cc	1:8500		1970	1980	....	10	Excellent	
III	1.0 cc	10 cc	1:8500	1:9250	2450	2210	240	....	Fair	Only fair condition 4 weeks later
IV	1.0 cc	10 cc	1:10000		2450	2350	100	....	Excellent	
V	10.0 cc	100 cc	1:5000	1:4500	2620	2400	220	....	Fair	Poor condition 4 weeks later
VI	10.0 cc	100 cc	1:4000		2160	1870	290	....	Fair	Died on 20th day

*Intravenous Injections. †Daily for ten days.

FORMATION OF THE INTRANUCLEAR ROD IN SUCCINEA OVALIS SAY.

C. P. HICKMAN, DePauw University.

The view of the older cytologists that the centriole and accessory structure axial filament were confined to the middle piece and base of the sperm head has been disproven in a number of cases brought to light in the past few years. It is now definitely decided that, in some forms at least, there are prolongations of the centriole extending through the entire head of the sperm. Whether or not one of these structures (commonly known as intranuclear rods) represent the actual centriole itself has not been proven. But it is quite evident that this rod does represent a definite part of the main axis around which the sperm is built. Or, in other words the intranuclear rod may be considered to play the same part in the sperm head that the axial filament plays in the tail of the sperm.

Although the presence of an intranuclar rod has been reported by a number of observers, its exact mode of origin seems to vary greatly with the different forms in which it has been described. It is possible, of course, that there can be considerable variation in its mode of formation, but it is also quite probable that a large percentage of this lack of uniformity has arisen out of the difficulties attending the study of the sperm head at the time when the rod is being formed. Only the most careful technique and under the most favorable circumstances will reveal the secrets of this baffling structure.

In the case of the common terrestrial pulmonate, *Succinea ovalis* Say, the intranuclear rod is formed in a manner entirely different from that described in other forms. This snail, in common with other pulmonates, has two centrioles in its spermatid stages. One of the centrioles is found located eventually at the periphery of the sperm nucleus and is known as the proximal centriole; the other is found in that part of the spermatid that becomes the tail and is called the distal centriole. In the early history of the spermatid the two centrioles which at first lie close together separate and an axial filament grows between them (figs. 1 and 2). The proximal centriole grows toward the nuclear membrane, becomes thick and rod-like and finally penetrates the nuclear membrane, thus partially extending into the nuclear cavity (fig. 3).

As the spermatid elongates a very fine projection, the anterior axial filament, grows forward from the proximal centriole into the nuclear cavity, finally reaching a dense darkly-staining mass located within the central region of the nucleus (fig. 4). Later, the rod or filament reaches the nuclear membrane at the point where the future acrosome is laid down (fig. 5).

Just as soon as the anterior axial filament has reached through the nucleus, the darkly-staining mass of material begins to undergo a change. At first, a prolongation of the mass is sent along the filament toward the anterior pole (fig. 6), and later another prelongation of the mass is sent toward the proximal centriole (fig. 7). In later

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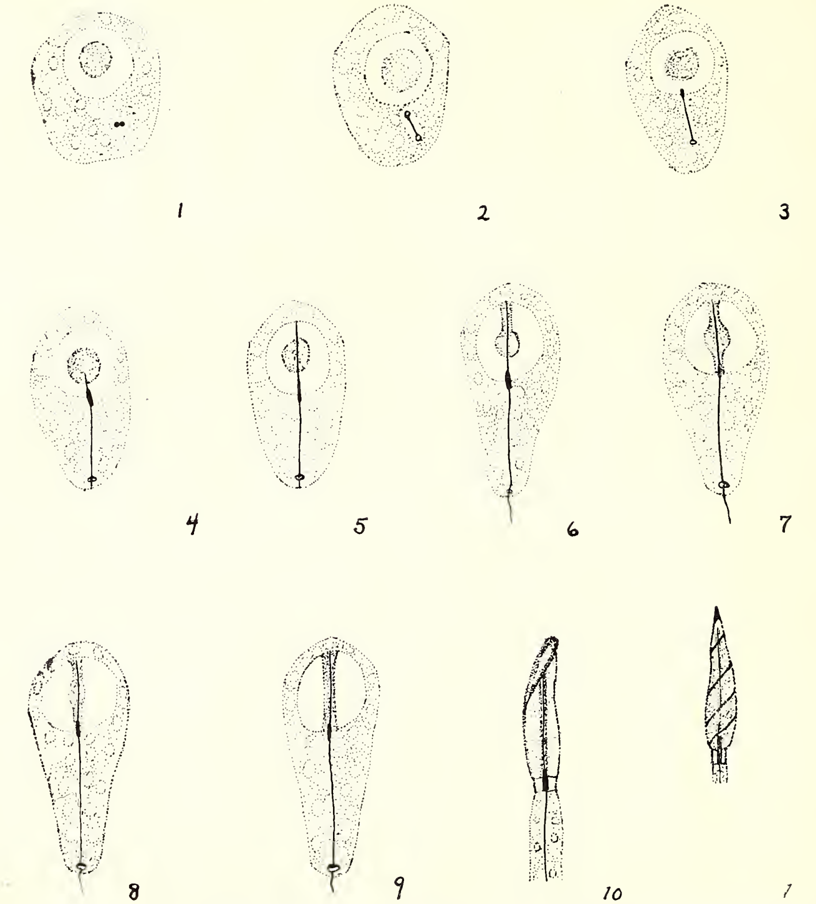

Figs. 1-11. 1-4. Early spermatids. Development and growth of centrioles and axial filaments; 5-6. Later spermatids, showing origin of anterior axial filament; 7-9. Still later spermatids. Sheath is being formed around the filament; 10. A late stage in the formation of the sperm head; 11. Mature sperm head. Intranuclear rod shows faintly after destaining. (All figures drawn with a 2mm. Leitz apochromatic objective and a No. 12 ocular.)

stages this mass is closely applied to the filament, forming a very compact sheath (figs. 8 and 9). The whole structure is now known as the intra-nuclear rod and can be be made out in all later stages with the proper technique.

In the mature sperm head the rod is most commonly obscured by the deep stain of the dense chromatin. However, its presence can be detected by destaining or by maceration of the sperm (fig. 11).

From this account, it is seen that there is no evidence in this form for the view that the mitochondria help form the sheath around the filament, such as has been described for certain prosobranchs. The sheath here is formed entirely from a darkly-staining mass of material which resembles chromatin in many respects. Whether or not it is chromatin has not yet been determined with certainty.

TWO YEARS BIRD-BANDING AT WEST LAFAYETTE, INDIANA.

LOUIS AGASSIZ TEST, Purdue University.

Bird-banding was taken up as a recreational hobby and operations began in West Lafayette in the fall of 1924. There is no other station in West Lafayette, the nearest one being at Crawfordsville. The first capture was two bronzed grackles on September 29, 1924. As two and one-half months each summer have been spent away from West Lafayette, 20 months represents the actual period of operations.

In this time 633 captures have been recorded and 500 individuals banded. The 133 recaptures or reports are 21.4 per cent of the total number of captures.

The number of species represented is 32. Of these 12 species show no record of recaptures or reports. Several of these are represented by a single individual and only three by more than two individuals. The species with the largest number of individuals banded is bronzed grackle with 134, followed by chimney swifts with 84 (these represent a single catch), slate-colored junco 81, robins 39, bluejay 25 and white-crowned sparrows 22. The accompanying list shows the number of each species banded with recaptures and reports.

In recaptures robins lead with 32, one individual being recaptured eight times, the largest number for any single individual. Strangely enough, of all the species showing recaptures the bronzed grackle shows the lowest percentage, 6.7 per cent or 9 out of 134. The tufted titmouse shows the highest percentage of recaptures, 200 per cent, or eight out of four individuals banded. Of the species with no repeats or recoveries those with more than three individuals banded are chimney swift 84, all of which were banded at one time and no other captures attempted, tree sparrow 16 and red-headed woodpecker 6.

Two reports only have been received from other parts of the country. Mourning dove No. 284,059 banded April 19, 1925, was killed at Cameron, Texas, October 14, 1925. Bronzed grackle No. 284,062 banded April 23, 1925, was killed at Tupelo, Miss., February 15, 1926.

There have been a few returns to our traps the season following banding. Downy woodpecker No. 256,921 ad. ♀ banded December 20, 1924, was recaptured November 2, 1925, and again November 20, 1926.

There have been three returns from bronzed grackles. No. 285,414 ad. ♂ banded March 13, 1925, was recaptured in good condition April 26, 1926, being caught both times in the drop trap. Number 339,852 ad. ♀ banded April 4, 1925, was recaptured May 22, 1926. The band had in some way become lapped and made a depression on the leg. The band was readjusted before the bird was released. This bird had an unusually purple head, a characteristic noted both times it was captured. Number 284,055 banded April 13, 1925, was found dead on the Purdue campus July 16, 1926.

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Slate-colored juncos have but one return out of 21 birds banded the first winter. Number 146,110 banded Dec. 22, 1924, was recaptured January 26, 1926.

House wrens show one return. Number A10,827 banded April 28, 1925, repeated May 4, 1925, and probably was one of a pair nesting in the yard. It was recaptured May 11, 1926, and again nested in the yard but in another wren house.

There are two returns for robins. Number 342,797 ad. ♀ banded June 5, 1925, was recaptured April 2, 1926. Number 342,784 ad. ♂ banded May 15, 1925, repeated May 17, 1925, and was recaptured March 30, 1926. This is our most interesting return. The note of the first banding would indicate that it was a perfectly normal male robin as there was no mention of any unusual features. When recaptured on March 30, 1926, it was about one-third albino, a very strikingly colored bird due to numerous large white patches. It had been noted in the vicinity since March 18 and was observed to be banded but its identification as robin No. 342,784 was a surprise. It evidently nested in the neighborhood in 1926 for it was later seen feeding young on the lawn and one of these was captured and banded June 9. Both will be eagerly watched for next spring.

Robins have mostly been caught during the nesting season or in snow storms. At other times the type of bait used does not seem to attract them. It is also interesting that in 1925 there were many repeats, one bird repeating eight times and two seven times each, seven of the 13 adults captured that year repeating. In 1926 only two of the 11 birds banded repeated.

Some interesting data have been obtained from the banded juncos. From October until well through December most of the birds captured have been new indivuals with very few repeats. In January and February a large percentage of the captures are repeats. Again in March and April new birds are banded with very few repeats. Interesting repeats last winter were No. 78,168 ♀ banded December 19, 1925, repeated January 1, February 11 and 27, and March 27, 1926. Number 78,176 ♀ banded January 11, repeated January 14, 27, February 12 and 27, 1926. These results would seem to indicate that the earlier migrants in the fall winter south of West Lafayette, while later migrants stay with us all winter living in rather restricted areas. It is our hope to get further data on this species during the present winter and if possible similar data on other species.

Seven types of traps have been used mostly home made. In effectiveness the simple drop trap seems to lead with the government sparrow trap a close second. A drop front trap placed on a platform in a tree gives fairly good results for bluejays and tree climbing birds. Other traps are a tree trunk trap for tree climbing birds, a clover leaf type trap, which so far has not proved very effective and an "Everset" sparrow trap which has caught nothing but English sparrows and one house wren. A chimney trap for chimney swifts has been used once when 240 swifts were caught in it at one time. Unfortunately only 84 bands were available suitable for banding the swifts.

The bait used on the ground traps has been mostly bread and chick feed with sometimes sunflower and hemp seed. For the tree traps suet has been found the best.

Birds Banded at West Lafayette, Ind., Sept. 29, 1924 to Dec. 1, 1926

Species	No. Banded	Repeats and Returns	Species	No. Banded	Repeats and Returns
Bob White, *Colinus virginianus*	2	2	Tree sparrow, *Spizella monticola*	16	0
Mourning dove, *Zenaidura maeroura carolinensis*	8	1	Chipping sparrow, *Spizella passerina*	3	1
Downy woodpecker, *Dryobates pubescens medianus*	7	9	Field sparrow, *Spizella pusilla*	1	0
Red-headed woodpecker, *Melanerpes erytrocephalus*	6	0	Slate-colored junco, *Junco hyemalis*	81	27
Red-bellied woodpecker, *Centurus carolinus*	1	0	Song sparrow, *Melospiza melodia*	9	2
Flicker, *Colaptes auratus*	3	2	Lincoln's sparrow, *Melospiza lincolnii*	2	1
Chimney swift, *Choetura pelagica*	84	0	Cardinal, *Cardinalis cardinalis*	5	1
Bluejay, *Cyanocitta cristata*	25	7	Catbird, *Dumetalla carolinensis*	6	1
Cowbird, *Molothrus ater*	1	0	Brown Thrasher, *Toxostoma rufum*	13	9
Meadowlark, *Sturnella magna*	1	0	House Wren, *Troglodytes aedon*	5	3
Baltimore oriole, *Icterus galbula*	7	6	Brown creeper, *Certhia familiaris americana*	1	1
Bronzed grackle, *Quiscalus quiscula aeneus*	134	9	Whitebreastednuthatch, *Citta carolinensis*	6	5
Savannah sparrow, *Passerculus sandwichensis savanna*	1	0	Tufted titmouse, *Boeolophus bicolor*	4	8
White-crowned sparrow, *Zenotrichia leucophrys*	22	7	Wilson's thrush, *Hylocichla fuscescens*	1	0
White-throated sparrow, *Zenotrichia albicollis*	2	0	Gray-cheeked thrush, *Hylocichla aliciae*	2	0
			Hermet thrush, *Hylocichla guttata pallasii*	2	0
			American robin, *Planesticus migratorius*	39	32

Total species 32
Total individuals 500
Total captures 633
Total recoveries ...... 133 or 21.4 per cent of total individuals captured.
Species no repeats ..... 12 or 37.5 per cent of total species.

NOTES ON SOME BIRDS OF ANDERSON, INDIANA.

CHARLES PIPER SMITH, San Jose, California.

It is rather a shock to open a volume and find oneself face to face with a title that carries you back a quarter of a century, the paper treating your boyhood hobby at your boyhood "stomping" ground. Such was my experience as I opened my copy of the Academy's Proceedings of 1925, Esten's interesting report on the birds of Madison County being the paper concerned.

During the years 1895 to 1900, both inclusive, Anderson was my home town, and during each of those six seasons the birds received most of my spare time. Extensive notes in diary form, were recorded and most of these are now available for reference. While Esten's experiences and mine check to a considerable degree, certain definite divergencies seem to warrant published comment. It is well known that two or more persons, traveling the same territory at the same time, will have different experiences with the birds. It is also well known that bird populations vary, from year to year, in a given region; this, of course, being partly due to man's readjustments of the fields, thickets, and woodlands, thus affecting the haunts and habits of the birds. Draining of certain areas and reclaiming of wet, tangled thickets for corn-planting was rapidly taking place in my day. Hence I assume that Esten's "country about Anderson" and mine must have differed in many details. Accordingly I now make a few comments anent discrepancies in our respective experiences, etc. To make reference to Esten's paper easy, I use the numbers and sequence of his catalog.

15. (221) American coot. My experience with this species about tallies with Esten and Gilpin's. On April 17, 1897 I caught a disabled coot, some three miles north of Anderson, along a small stream; this the only specimen I saw in the county.

16. (228) Woodcock. "A rare migrant" seems to be right. On April 24, 1900, I flushed a lone specimen in a woodlot about a mile south of the city,—my only record.

34. (387) Yellow-billed cuckoo. I considered this a common species. One nest was found in 1898, six in 1899 (May 18 to June 10), and five in 1900 (May to June 9).

35. (388) Black-billed cuckoo. Recognized by me just once, when a nest with young was found June 9, 1896.

41. (409) Red-bellied woodpecker. Frequently seen by me. On one occasion, I noticed a pair of these birds separated by a red-headed woodpecker. One of the "zebra-backs" was cornered in an excavation in a limb of a tree, and the minute it showed its head at the entrance-exit, the red-head would dash toward the prisoner, uttering sharp, scolding notes. The head of the timid prisoner quickly disappeared at each onslaught of the tyrant, which then dashed at the equally timid,

alternately approaching and retreating, unimprisoned mate. The cries of the excited birds attracted my attention to the episode, and when I left the comic tragedy was "still on".

53. (465) Acadian flycatcher. "Rare summer resident" certainly attracted my attention, yet the species may be erratic in its summer distribution, since I did not recognize it during my first four years of observations. But in 1899 I found eight nests (May 30 to June 12), and in 1900, 15 nests (May 30 to June 16). These nests were in ironwood (Carpinus), beech, maple, elm, hawthorn and flowering dogwood, the extremes of elevation above the ground, four and nineteen feet.

54. (466a) Alder flycatcher. I look with interest at the statement, "Rare migrant May 17 to June 17 and very rare summer resident". I found five nests, as follows: June 25, 1897, June 10 and 22, 1899, and June 16 and 23, 1900. Most, or all, of these were located in a wet thicket that was rapidly being changed into corn land during those years, this region now, perhaps, being wholly unattractive to this species. Yet Esten's dates suggest that this bird may still nest about Anderson, perhaps more frequently than his experiences show.

—. (474) Horned lark. Not mentioned by Esten; perhaps inadvertently omitted from his catalog. I noted this species April 8 and 9, 1897, and March 15 and May 7, 1898. Probably my birds were of the race, or subspecies, called the prairie horned lark.

59. (495) Cowbird. Another matter of special interest to me is that Esten found the cowbird, seemingly, favoring the nests of the song sparrow, thrasher, and towhee. Have the cowbirds changed their habits since my day; found out in some way that those birds make better foster-parents for their young? My records show that none of my 17 nests of song sparrow, three nests of towhee, or 15 nests of thrasher were "blessed" with the uninvited guests; but cowbirds had "favored" six of my nests of indigo bunting, five nests of each chat and red-eyed vireo, two nests of each cardinal and white-eyed (?) vireo, and one nest of each acadian flycatcher, yellow warbler, yellow-throat, catbird and wood thrush.

70. (542a) Savanna sparrow. The expression, "rare migrant", agrees with my experience, I having seen the species at "Esten's locality", April 2 and 3, 1899.

71. (546) Grasshopper sparrow. Considered common by me, at least one summer, in fields two or three miles northwest of town, the characteristic song often heard and easily recognized.

86. (595) Rose-breasted grosbeak. This bird was first seen by me on May 22, 1897, in a swampy thicket northwest of North Anderson, a male "rose bud" being found covering a set of five eggs. At the same locality additional nests were found on May 27 and June 3, 1899, and June 8, 1900. This was the thicket of my Traill (alder) flycatchers, and may have, long since, been reclaimed for agricultural purposes, leaving no nesting retreats for these two retiring species.

104. (631) White-eyed vireo. "Frequent summer resident" must mean that this species has "moved to Anderson" since my day. I spent

much time watching for this bird and actually identified it just once or twice, assigning, with a question mark, three nests to this species.

108. (641) Blue-winged warbler. "Frequent to common migrant." In 1900 this was a common breeding species in the woodlands northwest of the Madison Avenue Bridge. I found fledglings out of the nest, but failed to find a nest with eggs.

130. (683) Yellow-breasted chat. "A rare summer resident." What has become of the chats? I considered this one of the really common summer birds, the characteristic whistling being one of the familiar sounds of the thickets everywhere. My records note three nests in 1895, one in each 1896 and 1897, three in 1898, six in 1899, and five in 1900.

137. (719) Bewick wren. "A very rare summer resident. One record, Apr. 30. . . ." My first record of this bird for 1898 was March 23, the latest April 17. My first record for 1899 was April 12. No record for 1900, and no record later than April 17. I doubt that it nested about Anderson in those days, the house wren being the breeding species.

149. (751) Blue-gray gnatcatcher. Evidently not found nesting by either Esten or Gilpin, as the species is listed as a "migrant." I found a nest, with young, on June 5, 1899, and located two pairs building, on May 6, 1900, followed by a third nest, with five eggs, on May 20.

SOME RESULTS OF A BIRD CENSUS.

Will Scott, Indiana University.

On April 10 and May 22 of 1926, a bird census was taken in Bloomington, Indiana, a city whose population is 15,000 and whose area is approximately 1,500 acres. Some of the results of this census are of general interest.

The observations were made by a class in ornithology, all of whom had had one or more years of university training. Fifteen were distinctly superior students. Six could recognize 50 or more birds when they entered the course. The class had worked intensively on birds since February 1.

Certain streets were selected at approximately regular intervals. Two or four students were assigned to a street. Usually two worked on each side. The birds were identified and counted on the street and the lots abutting. Six streets running east and west and six streets running north and south were used. The sections between each intersection were counted and calculated separately. Two sources of error are apparent. Some birds may have been missed and some birds may have been counted twice. These two sources of error tend to correct each other. How nearly they balance can not be determined.

The birds were assumed to be evenly distributed on each side of a street to a line bisecting the area between it and the adjacent parallel street along which counts were made. These areas are rectangles and from a map of known scale the number of birds in each area and the total for the city were calculated.

Meadow larks, mocking birds and a few others were seen only near the edge of the town. The identification of the vireos and warblers by some of the class could not be relied upon absolutely. By May 22 the leaves added to the difficulty of identification of these forms unless the song was known. Some species like the martins occurred very locally.

Omitting these three groups, there remain eight species that were numerous and generally distributed. They constituted more than 90 per cent of the total.

These eight species were the imported English sparrow, *Passeres domesticus domesticus* L.; the robin, *Planesticus migratorius migratorius* L.; the northern flicker, *Colaptes auratus auratus* Bangs; the jay, *Cyanocitta cristata cristata* L.; the bronze grackle, *Quiscalus quiscala aeneus* Ridgway; the mourning dove, *Zenaidura macroura carolinensis* L.; the brown thrasher, *Toxostoma rufum* L.; and the catbird, *Dumetella carolinensis* L.

Table I shows the total number of these eight species for the whole area on the two dates. In the last column is given the percentage of increase or decrease and in column one is indicated the number of eggs each species lays.

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TABLE I. Total Number of Birds for the Area Covered

Kind	No. Eggs	April 10	May 22	% Change
English Sparrow	6-9	3,675	11,655	217
Robin	4-6	735	1,168	58
Flicker	5-9	84	72	—14
Jay	3-6	118	439	270
Grackle	4-7	214	568	165
Dove	1-2	37	400	981
Thrasher	4-5	22	106	290
Catbird	4-5	13	433	3307

NOTE: Dove and Catbird evidently influenced by migration.

The decrease in the number of flickers may be accounted for by the fact that some were laying and others incubating on the last date. Since the flickers nest in holes the incubating birds could not be observed.

Besides the destruction by cats and other enemies, the major factors that influence the number of birds in our latitude during April and May are migration and reproduction.

Migration is clearly a very potent factor in the case of the dove and the catbird. The doves in part at least may simply have migrated from the field of the surrounding country to the towns to nest, since flocks of doves had been observed in these fields since February.

If a pair of birds produce four young the increase in population would be 200 per cent. This is most nearly approximated by the English sparrow, jay, grackle, and thrasher.

TABLE II. Comparison of Bloomington records with those reported by Forbes for Illnois

	Urban	Rural	
	Bloomington	Illinois	Illinois
		Autumn	Summer
English Sparrow	4,975	295	117
Robin	711	11	16
Flicker	30	11	16
Jay	187	10	....
Grackle	241	94	75
Dove	170	33	38
Thrasher	45	....	8
Catbird	197	....	....

In the fall of 1906 Forbes sent two observers into the field from August 28 to October 17. They made a quantitative estimate of the bird population of the state on a cross-section of the state at the latitude of Danville and Quincy. The following summer they made a similar estimate on a longitudinal section of the state. Seven of the eight birds here considered are in their lists. I have reduced all observations to number per square mile. The numbers so obtained are given in table II. The nearest approach to equality is in the case of the flicker. The number for the town was nearly twice that observed in the country. There were nearly 17 times as many English sparrows in the town as were observed on the Illinois farms.

TABLE III. Total bird population per square mile.

Bloomington (May)	1,359
Illinois (June, July, August)	527
Illinois (August, October)	579

The total bird population per square mile is given in table III. This indicates that there were more than twice as many birds in the area here considered than in the rural Illinois area.

Granting that the data in both cases are reliable, it means that either the general avifauna has increased from 1906 to 1926, for which there is no corroborative evidence, or that the bird population is denser in the town, at least during the spring. All the species under consideration nest in trees. The town in which the observations were made has more trees and shrubs than any adjacent area. Whether this density of bird population is maintained during the summer is not known. A midsummer census would yield significant data.

The observations here presented indicate that some birds do "come to town" to nest. They also indicate that nesting sites must be provided if tree nesting species are to be attracted and maintained near cultivated fields.

GYNANDROMORPHIC EARWIGS.

W. P. MORGAN, Indiana Central College.

While making observations on live earwigs, *Forficula auricularia,* an unusual individual attracted my attention. This earwig was peculiar in that one of the jaws of its forceps was of the male type while the other jaw was that of a female. In *F. auricularia,* as in most of the other earwigs, the forceps differ greatly in the two sexes.

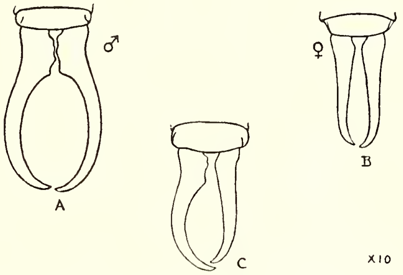

Fig. 1. A, forceps of adult male (long forceps variety) ; B, forceps of adult female; C, forceps of typical gynandromorph. The body lengths of all three earwigs whose forceps are shown in the figure were about the same.

As shown in figure 1, A, the forceps of the male have broad, flat bases with inner edges resembling irregular teeth. The distal portion forms board, caliper-like curves ending in sharp, pointed tips. There is a great variation in the length and curvature of the male forceps of *Forficula auricularia* which has been described by Bateson and Brindley.[1] This variation is dimorphic, ranging in forcep length about 3.5 mm. and about 7 mm.[2] These males with long forceps have been given the variety name of *forcipata* (Stephens).

The forceps of the adult females are nearly straight with their sharp-pointed tips curved inward (fig. 1, B). The bases are not as wide and flat, and the inner edges lack the tooth-like irregularities in outline seen in the forceps of males of this species.

Since several hundred dissections for cytological study have always shown the sex of the individual to be that indicated by the forceps, it was concluded that the abnormal earwig was a gynandromorph similar to those reported in other insect orders. A careful examination of about 3,000 earwigs of this species yielded 6 more abnormal individuals similar to the first. Figure 1, C, shows the forceps of one of these earwigs. The left jaw of the forceps is similar to that of the male, while the right resembles that of the female. This right jaw

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[1] Bateson and Brindley. Proc. Zool. Soc. London, 1892.

[2] Fulton, B. B. Oregon Agric. Exp. Station Bull. No. 207, 1924.

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does not represent a portion of the nymphal forceps abnormally retained from the last instar stage. The instar forceps are much more slender with narrow bases.

The gonads were removed from all of the gynandromorphic earwigs and fixed for cytological study. From a superficial examination at the time of their dissection no conclusions could be drawn as to the irregularities in the morphology of the gonads and the accessory structures. At present I am unable to say whether or not this abnormal condition is accompanied by an abnormal histological development of the gonad, nor have I been able to show that the gynandromorphic forceps are associated with parasitized individuals. Several of these points may be cleared up after the material is sectioned. It is quite probable that gynandromorphic earwigs, especially in the species *F. auricularia,* are fairly common, but the fact that the abnormalities are not conspicuous in the field possibly accounts for their having escaped the attention of observers.

A NOTE ON THE MODE OF DISTRIBUTION OF EARWIGS.

W. P. MORGAN, Indiana Central College.

Interest in the habits of the European earwigs, *Forficula auricularia,* has recently been revived due to its infestation in the region of Portland, Oregon. Some observers, especially in the newspapers, have doubted the harmful effects of the earwig as a pest. Although these insects are probably blamed for damage they have not done, nevertheless their omnivorous habits and ability to live under the most adverse conditions mark them as being potentially harmful. Our native earwigs should not be indicted with the European species, from which they differ in many respects. In the feeding habits of the four native species studied in the laboratory I find them to be essentially beneficial since they show a preference for feeding on other insects.

How rapidly the European earwig will extend its range and whether or not it will ever become a common pest in our inland cities is a matter of conjecture. There is an extensive literature based on observations of this species. Several authors have discussed its means of distribution but apparently one mode has escaped their attention; that is, water.[1]

Especial attention was given to the above item during some laboratory observation on earwigs collected in the locality of Portland, Oregon. The European earwigs are very efficient swimmers, although they probably never take to this mode of locomotion except by accident. Experiments with *F. auricularia* showed it to float as readily as a piece of cork and the oily surface of its body seemed to protect it even when submerged for several seconds. Adult females kept floating for 24 hours were as active as they were when placed in the water. Nymphs were drowned after a few hours, while mature males were nearly as resistant to the effects of water as the females.

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[1] Earwigs are known to be transported with objects shipped by boat but in this case the insects do not actually come in contact with the water.

Earwigs cluster under objects such as leaves, sticks and paper which are easily washed into gutters and streams during rains. It is quite probable that these floating objects often carry earwigs a great distance and deposit them in new regions, thus extending their range. The fact that the earwigs may be submerged for several seconds without injury suggests the possibility that they may even pass for some distance through closed sewers without being drowned. These observations seem to indicate that local streams and their tributaries may be factors in the distribution of the European earwig.

HOG LUNG-WORMS: CORRECTION OF PREVIOUS PAPERS.

GEORGE ZEBROWSKI, Villa Nova College, Pa.

The corrections embodied in this article refer to two previous reports published by the writer in these Proceedings. The first paper appeared in vol. 21, pp. 265-281; the second in vol. 23, pp. 353-366. In both of these papers there are a few points which a more thorough revision has shown to be in error, and which accordingly require correction. In the following tabulation the errors and corrections are presented in the sequence in which they occurred in the text.

Page 266, line 1, sub-family Metastrongylidae should read sub-family Metastrongylinae.

Page 266, under Morphology, occurs the following statement: "In the female the oviduct becomes continuous with the uterus, a short distance behind the esophagus. It then pursues a course parallel to the intestine, until it terminates in the vulva on a slight prominence in front of the anus." From this ambiguous description one would infer that there is a single oviduct and ovary, whereas, in common with other members of this genus, there are two ovaries. The concluding sentence of this same paragraph contains another astonishing statement: "During copulation the male grasps the female and impregnates her by inserting the spicules mentioned, into any region of her body, * * * so that they penetrate to the uterus. This ridiculous statement deserves no further comment other than the explanation that it is a typographical error, the correct phraseology reading, "into a definite region of her body, the vulva."

The term lesion is in most instances used as synonymous with the term infarct.

The classification in the preliminary report, p. 265, and the host list in the supplement, p. 353, are of course compilations and should have been acknowledged. At this late date the writer is uncertain as to their source.

Page 355, line 8, 90°C. should read 60°C.

NOTES ON INDIANA AMPHIBIANS AND REPTILES.

GEORGE S. MYERS, Stanford University, Calif.

The following notes are supplemental to my synopsis of Indiana amphibians and reptiles in last year's "Proceedings" (pp. 277-294). A few new records are added, mostly from material collected personally.

In mentioning papers since Hay (1893), I omitted Blatchley's second report on the batrachians and reptiles of Vigo County, *24th Ann. Rept. Indiana Dept. Geol. Nat. Res.*, (1899) 1900, pp. 537-552. Evermann & Clark, *Lake Maxinkuckee*, 1920, give some records, mostly previously published in these "Proceedings." Blanchard has recently published an interesting paper on some southern Indiana material, *Papers Michigan Acad. Sci. Art. Lett.*, V, (1925) 1926, pp. 367-388. Dunn's *The Salamanders of the family Plethodontidæ*, Smith College, 1926, deals with all the Indiana Plethodonts and gives many records.

AMPHIBIANS.

Ambystoma tigrinum (Green). Taken at Bloomington and Leonard's Springs near Bloomington.

Ambystoma jeffersonianum (Green). Bloomington.

Triturus viridescens viridescens (Rafinesque). Ponds near Bloomington. As McAtee has noticed, the red land form seems to be absent here. This is also true of *Triturus viridescens symmetricus* (Harlan)[1] at Wilmington, North Carolina, contrary to my report in *Copeia*, no. 131, 1924, p. 59. The "land forms" received from there were merely some of a large number of the water form that escaped when a vessel holding them was overturned, according to Mrs. Cummings. They had partially assumed the rough skin of the land form. Noble, *Amer. Mus. Novitates*, no. 228, 1926, has discussed this phase of the habits of the newt.

Eurycea bislineata bislineata (Green). Clifty Creek, Madison; Bloomington; common everywhere in southern Indiana along brooks.

Eurycea lucifuga Rafinesque. Cave at Leonard's Springs near Bloomington. One was found walking on the grass after a rain on the University campus at Bloomington.

Plethodon cinereus (Green). One with red back from above Bloomington city water-works.

Plethodon dorsalis (Cope). Very common about Bloomington. It is easily distinguished from the last by the scalloped border of the reddish dorsal band; the number of costal grooves varies to 18. In *cinereus* the edge of the dorsal band is even. Blanchard has treated *dorsalis* as a variety of *cinereus*, but the fact that they both inhabit

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[1] Symmetricus is an older name than dorsalis.

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the same region in Indiana yet do not intergrade seems sufficient for holding them distinct.

Desmognathus fuscus fuscus (Rafinesque). Clifty Creek, Madison. The characteristic physiognomy of this species, not mentioned in the synopsis, distinguishes it from all other Indiana Plethodontidæ. The head is large, smooth, and rather pointed, while the eyes are very prominent. The under jaw is immovable and the mouth is opened by raising the head.

Bufo fowleri Garman. The common toad at Bloomington. I have heard it at Madison. I believe that it will be found throughout the state; I heard what seemed to be a faint *fowleri* call at Decatur. On the other hand *B. americanus* is not found at Bloomington and is probably confined to northern Indiana. Blanchard says that Hahn reported no Bufo from near Mitchell. This is an obvious error, for Hahn reported "*B. lentiginosus americanus*" from Mitchell, but in the footnote it is stated that the Mitchell specimens were identified as *B. fowleri* by Miss Dickerson (Hahn, 1908, p. 557).

Acris gryllus (LeConte). Bloomington; Helmsburg; Madison; common everywhere in the southern part of the state.

Hyla (Pseudacris) triseriata Wied. Swamp cricket frogs are heard sparingly about Bloomington when *H. crucifera* is in song, in early spring. They are very elusive; the few captured were of this species.

Hyla crucifera Wied. Bloomington. Peepers are heard from ponds and swamps everywhere in southern Indiana in early spring. The specific name should be spelled as here given.

Hyla versicolor versicolor (LeConte). Gray tree frogs are rather common about Bloomington, but almost never captured. They breed in the pond behind Residence Hall on the Indiana University campus. Heard in Clifty Falls Park, Madison.

Rana pipiens pipiens (Schreber). Bloomington. Seldom seen. Weed's *R. pipiens burnsi* from Minnesota seems to me worthy of recognition, hence the above name is used for the typical variety. I have examined a *burnsi* obtained from a Chicago dealer.

Rana areolata Baird and Girard. This extremely rare frog, known from only a few localities in the central states and but twice reported from Indiana, was discovered breeding in a small pond a mile west of Bloomington by Mr. Herman P. Wright and myself. It was once found in Benton County and two specimens were found in a sewer at Terre Haute and reported by Blatchley. The species has been seen alive in the field by scarcely a half dozen naturalists and no one has observed the breeding or obtained the eggs. Eggs were brought to the laboratory in Bloomington and the writer obtained a complete developmental series, with the exception of the early stages of the egg. The discovery has been reported in a more detailed manner in *Copeia* and an account of the development is in preparation.

The species may be known at all ages by the small, light edged spots over the back and sides, many being present below the lateral folds; the latter character is in marked contrast to *pipiens* and *palustris*, neither of these having so large a number below the folds. The very rough skin of the adults is unique among Indiana frogs. The newly transformed young often show a slight greenish cast to the ground color, but never decidedly so, and the ground tone of the adults is always grayish.

Rana clamitans Latreille. Bloomington, common.

Rana catesbeiana Shaw. I heard no adult bullfrogs near Bloomington, but a single young specimen was taken.

REPTILES.

Sceloporus undulatus (Latreille). One from below the University water-works, Bloomington. A lizard seen at Madison and described to me by Mr. Homer Bolen was without doubt this species.

Cnemidophorus sexlineatus (Linné). Blatchley has reported this species abundant in the Dunes, *22nd Ann. Rept. Indiana Dept. Geol. Nat. Res.*, (1897) 1898, p. 92.

Eumeces fasciatus (Linné). One small example from near Bloomington.

Section C2 of the key to lizards should have the following inserted: *Ear opening not denticulate.* To section C3 should be added: *Scales smooth, not enlarged on belly; ear opening denticulate along its anterior margin.*

Sistrurus catenatus catenatus (Rafinesque). One reliably reported from Winona Lake.

Heterodon contortrix (Linné). One near Friendship Cabin, Helmsburg.

Opheodrys æstivus (Linné). A green snake seen by Mr. Homer Bolen at Madison was probably this species.

Natrix sipedon sipedon (Linné). Bloomington.

Carphophis amœna helenæ (Kennicott). This name should supplant *C. amœna* in the synopsis.

Coluber constrictor constrictor (Say). One caught halfway between town and the University water-works, Bloomington.

Lampropeltis getulus nigra (Yarrow). A slow-moving blacksnake seen by Dr. N. E. Pearson and Mr. R. Voris in a tree near the University water-works, Bloomington, and described to me by them, must have been this snake rather than *Elaphe obsoleta obsoleta.* It is to be expected in this region.

Amyda spinifera (LeSueur). One half-grown in a tiny brook a mile below Helmsburg. The habitat was unusual.

Amyda ferox (Schneider). This southern species has been taken once at Madison and should be added to the synopsis. It resembles *spinifera* in the presence of conical tubercles on the anterior border of the "shell," but differs in having the head streaks uniting just in front of the orbits. The adults are plain in color, while the young are rather dark, with darker spots. The young *spinifera* has dark rings with light centers, these becoming indistinct with age.

Terrapene carolina carolina (Linné). Fairly common near Bloomington.

Terrapene ornata (Agassiz). Two live specimens are in the Steinhart Aquarium, San Francisco, Calif., taken at Lake Maxinkuckee in the fall of 1926 by Mr. H. Walton Clark. The yellow markings on the carapace, never very brilliant in *carolina,* are more regular and extremely bright and pretty in these two specimens.

A good start has been given to an accurate survey of Indiana herpetology by Blanchard's work, mentioned above. The few records I have here given add a little more. It is hoped that a resident Indiana zoologist may be found to carry on the work. Certain regions will yield more immediate results than others. Posey County, in the southwest tip of the state, especially needs exploration, in order to determine whether or not certain southern species extend their ranges to within the state limits. The ranges of certain other southern species up the Wabash Valley need to be determined. The relationships of the frogs of the *Rana pipiens-Rana sphenocephala* group in southern Indiana should be worked out; they may intergrade along the lower Wabash. The *radix-butleri* group of Thamnophis should be investigated in the state, and the status of *Lampropeltis getulus nigra* examined. The limits of the ranges of *Bufo fowleri* and *B. americanus* and of the two subspecies of *Coluber constrictor* should be ascertained. These and many other problems only await an interested worker to be solved. And when the fundamental systematic basis is established there are numberless problems in life histories and ecologic relations to be cleared up. There is a variety of field open unknown in ornithology, in which it is rare to find a fact not already recorded by the hundreds of workers. How many papers have we on the recognized economic value of the toads and frogs? And on birds—?

SOME SOURCES OF ORNITHOLOGICAL MATERIAL AND WHAT THEY TELL.

AMOS W. BUTLER, Indianapolis.

There are three collections in Cincinnati that are of interest to Indiana ornithologists, as well as to those interested in other branches of science. Each has an interesting history and an extensive scientific library. These three are the collections of Mr. Charles Dury, the Cincinnati Society of Natural History and the Cuvier Club, now the Cuvier Press Club.

Mr. Dury has been a collector and student for more than 60 years. He has preserved a large number of birds, some of them from Indiana, that have become rare or are now not found within the limits of our state.

The Cuvier Club was originally composed of an enthusiastic group of sportsmen who made trips to well-known hunting grounds. Two of their favorite localities in Indiana were the Kankakee Valley and White County. To these, 50 or more years ago, they went regularly. Whenever they found rare specimens to add to their collection they had them mounted. That work was done by Mr. Dury, who was an excellent taxidermist.

The Cincinnati Society of Natural History was at its best 40 to 50 years ago and its collections include many interesting specimens from the Ohio River region and along the Ohio-Indiana state line, besides some from within the limits of our state. The most important contribution to its ornithological material is the collection of Dr. Frank W. Langdon, one of the early students of birds in the vicinity of Cincinnati.

Recently I spent two days in Cincinnati and had the opportunity of looking through those collections with Mr. Dury. From them I made many notes, to some of which I herein refer. I have prepared these records because they should be printed and preserved.

Doubtless there are other specimens in these collections of special interest to Indiana students of birds that would be disclosed by a more extensive search.

SOME BIRDS IN CHARLES DURY'S COLLECTION.

Kirtland's Warbler. *Dendrioca kirtlandi* (Baird). Male. May 4, 1872; Avondale, Hamilton County, Ohio. Charles Dury, collector. "Two birds seen; thicket of low bushes." This is one of the early records of this rare and interesting bird which has more recently been taken in Indiana.

Prothonotary Warbler. *Protonotaria citrea* (Bodd.). English Lake, Ind., July 28, 1891, "Swamp." R. Hazen, collector. Breeding abun-

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dantly at English Lake in woodpecker holes in willow trees. Birds had an appreciation of beauty. They used bright colored feathers of the wood duck in their nests. (Dury.) There are four other specimens of this warbler in this collection from the same person on the same trip.

White-winged Crossbill. *Loxia leucoptera* Gmel. One specimen. Michigan City, Indiana, March 28, 1883; J. W. Byrkit. There are two specimens of this species in the Cuvier Club collection from same person, same place and date, donated by Charles Dury.

American Crossbill. *Loxia curvirosta minor* (Brehm). Two specimens. Michigan City, Indiana, March 28, 1883, J. W. Byrkitt. There is a specimen in Cuvier Club from Mr. Byrkit taken at the same time.

Both species of Crossbills were found in great numbers at Michigan City, Indiana, in the spring of 1883. The latter was much the more common. Many specimens were sent by Mr. Byrkit to Mr. Dury, who prepared them and supplied the Cincinnati Society of Natural History, the Cuvier Club and Dr. Frank W. Langdon with specimens. The same year Redpolls and Pine Siskins were common there.

Baird's Sandpiper. *Pisobia bairdi* (Coues). Female. Vicinity of Cincinnati, mouth of Little Miami River (Dury), October 27, 1878.

Black-bellied Plover. *Squatarola squatarola* (L.). Male. Hamilton County, Ohio, September 21, 1879. Killed near mouth of Little Miami River by Charles Dury. In Mr. Dury's collection.

Wilson's Phalarope. *Phalaropus tricolor* Vieill. Male. No. 776. Lake County, Indiana, May 23, 1871. "Not abundant." C. E. Aiken. A specimen, female, in the Cuvier Club Collection, No. 1288, Kouts, Indiana, April 30, 1890. J. W. Gano.

Eskimo Curlew. *Numenius borealis* (Forst.). March 15, 1879. Indiana. Mr. Dury says: "A party of Cincinnati shooters brought it back from near Chalmers, Indiana. It was tied in a bunch of Wilson's Snipe. I recognized it and mounted it." There are two specimens, Nos. 346 and 347, in the collection of the Cuvier Club, labeled "Indiana."

Evening Grosbeak. *Hesperiphona vespertina* (W. Coop.). Male. March 6, 1911, Glendale, Hamilton County, Ohio. Mr. Dury says: "A flock of 22 came in March, 1911, and stayed until early summer. They remained in one place until breeding time and suddenly left. Only about eight specimens were taken." He has two other specimens from the same flock, a male and female; from C. Allen, Hamilton County, Ohio, June 8, 1911.

CUVIER CLUB.

Wild Pigeon. *Ectopistes migratorius* (L.). Male. Indiana. From Charles Dury, February, 1879 (No. 127). Mr. Dury has two in his collection, a male and a female, both from Avondale, Ohio, March 7, 1878. "Birds very abundant in spring and fall. Shot in beech woods on Mitchell Avenue." Mr. Dury says: "Wild Pigeons nested once in scattered pairs in tall trees in Estes Woods five miles from Avondale, Hamilton County, Ohio. I saw the young birds, which were scarcely able to fly in August in the early '70's."

Snowy Owl. *Nyctea nyctea* (L.). Female. (No. 242.) English Lake, Indiana, 1877, L. A. Harris.

Double-crested Cormorant. *P. auritus auritus* (Sw.). Male. English Lake, Indiana. J. W. Beezley.

Snow Goose. *Chen hyperborea nivalis* (Forst.). Juv. Indiana near Chalmers.

Trumpeter Swan. *Olor buccinator* (Rich.). Taken 12 miles below Cincinnati on the Ohio River, in December, 1876. Three seen. Max Wocher.

Long-billed Curlew. *Numenius americanus* Wils. Male. A specimen in the collection from Indiana, marked English Lake. Cuvier Club 351.

Marbled Godwit. *Limosa fedoa* (L.). Four specimens marked "Indiana." Mr. Dury says it was formerly abundant at Chalmers.

Redbreasted Snipe or Long-billed Dowitcher. *Macrorhamphus scalopaceus* (Say). Female. April 30, 1890, Kouts, Indiana, No. 1287. J. W. Gano. There are two other specimens of this species in the collection marked "Indiana."

Upland Plover or Bartramian Sandpiper. *Bartramia longicanda* (Bechst.). The collection contains three Upland Plover marked "Indiana." Mr. Dury understands they were taken near Chalmers. He has in his collection skins and eggs of this species taken at that place.

American Avocet. *Recurvirostra americana* Gmel. No. 374—Calumet (River?), Illinois.

Swallow-tail Kite. *Elanoides forficatus* (L.). Male. Price Hill, Hamilton, County, Ohio.

Red-throated Loon. *Gavia stellata* (Pont.). Mouth Little Miami River (Hamilton County, Ohio). No. 1337. Cuvier Club.

Horned Grebe. *C. auritus* L. Two specimens, 28 and 29, Cuvier Club. English Lake (Indiana). J. W. Beezley.

American Golden Plover. *C. dominicus* Müll. Three specimens (399, 400, 401), two of them nearly full plumaged. Cuvier Club. "Indiana." Beezley and Carlisle.

Blue Goose. *Chen caerulescens* (Linn.). "Indiana." J. W. Beezley. Cuvier Club, 299.

Sandhill Crane. *Grus mexicana* (Müll.). Male. Indiana. L. A. Harris. Cuvier Club, 438.

White Pelican. *Pelecanus erythrorhynchos* Gmel. Sternum. Aurora, Indiana. About September 20, 1877. J. W. S.(horten). Dr. F W. Langdon collection. Possibly Mr. Shorten, who was a well-known taxidermist, mounted the bird for some customer and it is still preserved.

Caspian Tern. *Sterna caspia* Pallas. While it has been reported in Indiana and verified by specimens from the vicinity of Lake Michigan, one of which I have, Millers, Ind., September 27, 1898, F. M. Woodruff—records from the interior of the states between the Great Lakes and the Ohio River, are of interest. There are two of these birds in the Cuvier Collection; 113, female, Ross Lake, Ohio, October

9, 1883, from Mr. Rosa; 114, Little Miami River, Hamilton County, Ohio, October 16, 1883. A. Starbuck. Cuvier Club.

Franklin's Gull. *Larus franklini* Sw. and Rich. I add here a recent note from Pierce Brodkorb, Chicago, Illinois: "In the collection of Mr. J. Grafton Parker, Jr., now deposited in the Field Museum (Chicago) is a female Franklin's Gull, taken at Liverpool, Indiana, May 3, 1898." So far as I can recall this is the first record for Indiana verified by a specimen.

MEMBERS.[1]

FELLOWS.

Anderegg, Frederick O., Mellon Institute, Pittsburgh, Pa.	1918[2]	1924[3]
Anderson, Flora C., Indiana University, Bloomington	1914	1923
Andrews, F. M., 901 E. Tenth St., Bloomington	1896	1911
Arthur, Joseph C., 915 Columbia St., Lafayette	Charter	1893
Badertscher, J. A., 312 Fess Ave., Bloomington	1914	1917
Behrens, Charles A., 1020 Third St., West Lafayette	1916	1917
Bennett, Lee F., Box 225, Janesville, Wis.	1898	1916
Benton, Geo. W., 100 Washington Sq., c/o American Book Co., New York, N. Y.	Charter	1896
Bigney, Andrew J., Evansville College, Evansville	Charter	1897
Blanchard, William M., DePauw University, Greencastle	1909	1914
Blatchley, W. S., 1558 Park Ave., Indianapolis	Charter	1893
Breeze, Fred J., Ball Teachers College, Muncie	1898	1910
Bruce, Edwin M., 2108 N. Tenth St., Terre Haute	1918	1926
Bruner, Henry Lane, 324 S. Ritter Ave., Indianapolis	1892	1899
Bryan, William Lowe, Indiana University, Bloomington	1893	1914
Butler, Amos W., 52 Downey Ave., Indianapolis	Charter	1893
Carr, Ralph H., 27 N. Salisbury St., West Lafayette	1914	1922
Christy, O. B., Ball Teachers' College, Muncie	1919	1926
Cogshall, W. A., 423 S. Fess Ave., Bloomington	1905	1906
Coulter, Stanley, 126 State House, Indianapolis	Charter	1893
Culbertson, Glenn, Hanover College, Hanover	1895	1899
Cumings, Edgar Roscoe, 327 E. Second St., Bloomington	1900	1906
Davis, John J., Purdue University, Lafayette	1920	1924
Deam, Charles C., Bluffton	1900	1910
Dietz, Harry F., State Conservation Comm., Indianapolis	1909	1922
Dryer, Charles R., 325 Grove St., Fort Wayne	Charter	1897
Dutcher, J. B., 1212 Atwater Ave., Bloomington	1907	1915
Eigenmann, Carl H., 630 Atwater Ave., Bloomington	Charter	1893
Enders, Howard E., 249 Littleton St., West Lafayette	1906	1912
Fisher, Martin L., 325 Vine St., West Lafayette	1908	1919
Foley, Arthur L., 744 E. Third St., Bloomington	1894	1897
Friesner, Ray C., Butler College, Indianapolis	1919	1925
Gardner, Max W., Purdue Agri. Exp. Sta., Lafayette	1919	1923
Hansen, Albert A., Purdue Agr. Exp. Station, Lafayette	1921	1925
Hess, Walter N., DePauw University, Greencastle	1917	1923
Hessler, Robert, 25 S. Bolton Ave., Indianapolis	Charter	1899
Hoffer, George N., 434 Littleton St., West Lafayette	1922	1926
Hufford, Mason E., 514 S. Sluss Ave., Bloomington	1914	1916

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[1] Every effort has been made to obtain the correct address of each member.

[2] Date of election to Academy.

[3] Date of election to fellowship.

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Hyde, Roscoe R., 4101 Penhurst Ave., Baltimore, Md.	1909	1916
Jackson, Herbert S., Purdue Agr. Exp. Station, Lafayette	1915	1919
Kern, Frank D., Dept. of Botany, State College, Pa.	1905	1912
Koch, Edward W., 24 High St., Buffalo, N. Y.	1914	1917
Logan, Wm. N., 924 Atwater Ave., Bloomington	1916	1917
Lyon, Marcus Ward, 214 LaPorte Ave., South Bend	1922	1926
Mahin, Edward G., Notre Dame Univ., Notre Dame	1916	1922
Mains, E. B., 422 Waldron St., West Lafayette	1916	1925
Malott, Clyde A., 708 Woodlawn Ave., Bloomington	1914	1925
Markle, M. S., 528 National Ave., Richmond	1910	1919
Middleton, Arthur R., 705 Russell St., West Lafayette	1906	1918
Moenkhaus, W. J., 320 S. Fess Ave., Bloomington	1893	1901
Mottier, David M., 215 Forest Place, Bloomington	Charter	1893
Naylor, Joseph P., DePauw University, Greencastle	Charter	1903
Nieuwland, Father J. A., Notre Dame Univ., South Bend	1908	1914
Payne, Fernandus, 620 Ballantine Road, Bloomington	1913	1916
Ramsey, Rolla R., 615 E. Third St., Bloomington	1904	1906
Rettger, Louis J., 31 Gilbert Ave., Terre Haute	1893	1896
Rothrock, David A., 1000 Atwater Ave., Bloomington	1898	1906
Scott, Will, 525 S. Park Ave., Bloomington	1905	1914
Stoltz, Charles, 311 W. Jefferson Blvd., South Bend	1909	1919
Switzer, J. Elmer, 523 S. Park Ave., Bloomington	1923	1926
Tetrault, Phillip A., 124 Thornell St., W. Lafayette	1914	1925
Tucker, William Mottier, Indiana University, Bloomington	1910	1923
Van Hook, James M., 639 N. College, Ave., Bloomington	1909	1911
Visher, Stephen S., 817 E. Second St., Bloomington	1919	1924
Wade, Frank B., Shortridge High School, Indianapolis	1903	1914
Weatherwax, Paul, 416 S. Dunn St., Bloomington	1913	1922
Williamson, E. B., Bluffton	1911	1914
Wright, John S., 3718 N. Pennsylvania St., Indianapolis	1893	1894
Yuncker, Truman G., 203 Wood St., Greencastle	1919	1923

NON-RESIDENT MEMBERS AND FELLOWS.

Abbott, G. A., Univ. of N. D., Grand Forks, N. D., Fellow	1908
Aldrich, John Merton, Natl. Museum, Washington, D. C., Fellow	1918
Brannon, Melvin A., Univ. of Montana, Helena, Mont.	
Burrage, Severance, Univ. of Colo., Boulder, Colo., Fellow	1898
Campbell, D. H., Stanford University, Stanford, Cal.	
Clark, Howard W., Steinhart Aquarium, Golden Gate Park, San Francisco, Cal.	1900
Cook, Mel. T., Rio Piedras, Porto Rico, Fellow	1902
Coulter, John M., University of Chicago, Ill., Fellow	1893
Davis, B. M., Ann Arbor, Mich.	
Evermann, B. W., Calif. Acad. Sci., Golden Gate, San Francisco, Calif.[4]	
Goss, William Freeman M., Barnstable, Mass.	1893
Greene, Charles Wilson, 814 Virginia Ave., Columbia, Mo.[4]	
Hargitt, Charles W., Lyman Hall, Syracuse, N. Y.[4]	
Hay, Oliver Perry, U. S. Natl. Museum, Washington, D. C.	1893

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[4] Elected previous to 1891.

Jordan, David Starr, Stanford, Cal....................................1893
Kingsley, John S., 2500 Odor St., Berkeley, Cal.[4]..................
Knipp, Charles T., 915 W. Nevada St., Urbana, Ill.....................1894
MacDougal, Daniel Trambly, Desert Laboratory, Tucson, Ariz.[4]....
McMulen, Lynn B., Northern Ariz. Norm. School, Flagstaff, Ariz...1900
Ariz. 1900
Marsters, Vernon F., Kansas City, Mo., 123 Railway Exchange, Fellow 1893
Miller, John Anthony, Swarthmore, Pa., Fellow....................1904
Moore, George T., Mo. Botanical Garden, St. Louis, Mo...........1909
Noyes, William Albert, Urbana, Ill., Fellow.......................1893
Ransom, James H., James Millikin Univ., Decatur, Ill., Fellow.....1902
Springer, Alfred, 312 E. Second St., Cincinnati, Ohio..............
Swain, Joseph, Swarthmore, Pa., Fellow.........................1898
Von Kleinsmid, R. B., Univ. of So. California, Los Angeles, Calif...1920
Waldo, Clarence A., 45 W. 119th St., New York City, Fellow.......1893
Wiley, Harvey W., Woodward Bldg., Washington, D. C............1895
Zeleny, Charles, 1003 W. Illinois St., Urbana, Ill..................1904

ACTIVE MEMBERS.

Abbott, Raymond B., 339 Sylvia St., West Lafayette..............1924
Abel, Edward Larue, Box 642, Terre Haute........................1925
Acher, Rudolph A., Indiana State Normal School, Terre Haute.....1925
Adams, Esther, Butler Apts., Columbia, Mo.......................1923
Adams, Wm. B., 432 S. Walnut St., Bloomington...................1919
Addington, Archie, 507 S. Fess Ave., Bloomington................1921
Albertson, Rev. G. W., Dept. of Biol., Notre Dame, South Bend.....1925
Alleback, Theodore Henry, Emlenton, Pa..........................1926
Allee, W. R., 221 E. Fourth St., Bloomington......................1922
Allen, Dorothy, 1522 N. Tuxedo, Indianapolis......................1926
Allen, Frederick J., 112 S. Grant St., West Lafayette..............1924
Allen, Wm. Ray, University of Kentucky, Lexington, Ky..........1912
Allison, Robert V., Everglades Exp. Sta., Belle Glade, Fla.........1925
Allyn, Wm. Preston, 226 N. 6th St., Terre Haute..................1925
Alter, Chester M., R. R. 4, Rushville...........................1926
Alquisl, Francis N., 964 River St., Fitchburg, Mass..............1926
Amatis, Sister, St. Mary of the Woods..........................1925
Amidei, Tirzo Paul, 2684 Washington St., Gary....................1926
Armington, John H., U. S. Weather Bureau, Indianapolis..........1925
Atkins, Doro O., 1427 Columbia Ave., Indianapolis...............1926
Auble, Robt. N., 1121 Tecumseh St., Indianapolis..................1922
Austin, Raybrom C., 311 E Smith St., Bloomington...............1926
Ayres, Agnes W., 1003 State St., West Lafayette.................1923
Bailey, Clara Marie, Greencastle, Indiana, R. R. 3................1925
Bair, W. H., 145 Andrew Place, West Lafayette...................1924
Baker, Lora M., 424 N. Calvert Ave., Muncie.....................1920
Baker, Wm. F., Box 586, Carmel................................1914
Baldwin, Ira L., Dept. Agric. Bact., Univ. Wisconsin, Madison, Wis..1919
Barkley, Grace, 107 S. College, Greencastle......................1926

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[4] Elected previous to 1891.

Barnhill, Dr. J. F., Ind. Univ. School of Medicine, Indianapolis....1916
Barr, Harry L., 403 S. Lincoln Ave., Urbana, Ill...................1911
Bartle, Glenn Gardner, Kansas City Jr. College, Kansas City, Mo..1923
Beals, Colonzo C., R. R. No. 3, Mishawaka...................1915
Beck, Carol Harriet, R. R. No. 5, West Lafayette...............1923
Beck, John, R. R. J, Lafayette.................................1924
Bechtel, Albert R., 708 W. Wabash Ave., Crawfordsville...........1920
Beebe, Ralph E., 724 Ashland Ave., Muncie.......................1926
Beecher, Alva, 1010 E. Pike St., Crawfordsville..................1922
Begeman, Hilda, Horton House, Wellesley, Mass...................1919
Beghtel, Floyd E., Bot. Dept., Ind. Cent. College, Indianapolis.....1925
Belcher, Carl James, Frankfort, Indiana, R. R. 5..................1925
Bell, Alma Marie, 503 N. Main St., Harrisburg, Ill..............1922
Bell, Bessie, Logansport.......................................1926
Bennett, Wallis R., Endeavor, Wisconsin.........................1926
Benson, Wallace F., 215 Columbia, W. Lafayette.................1926
Berg, Geo. F., Jr., 1702 East 12th St., Indianapolis...............1922
Betzner, Ruth A., Bunker Hill..................................1926
Black, Homer F., 118 East 26th St., Chicago, Ill.................1916
Black, Roy D., 510 Jefferson St., Madison........................1925
Blalock, Grove Cleveland, 336 Lutz Ave., West Lafayette........1924
Blaydes, Glenn William, 95 Oak Hill Ave., Delaware, Ohio.........1923
Bloye, Amy Irene, 115 E. Columbia St., West Lafayette...........1923
Bockstahler, Harrold W., 27 Russell St., W. Lafayette..............1926
Bockstahler, Lester, 104 Haven House, Evanston, Ill..............1920
Bodine, Mrs. Emma, 4 Mills Plate, Crawfordsville................1921
Bolen, H. R., S. E. Mo. St. Teachers' College, Cape Girardeau, Mo...1922
Bolenbaugh, Alta, 350 S. College Ave., Bloomington..............1924
Bolinger, Maurice G., 140 N. Grant St., W. Lafayette..............1926
Bond, Dr. Chas. S., 112 N. Tenth St., Richmond...................1900
Bond, Dr. Geo. S., 2104 N. New Jersey St., Indianapolis..........1916
Boots, Edwin B., 125 North 6th St., West Terre Haute...........1922
Bourke, Adolphus A., 2304 Liberty Ave., Terre Haute...........1909
Brackmier, Gladys H., 126 Spencer Ave., Indianapolis.............1926
Bradt, Wilber E., 300 Montgomery St., Pullman, Wash..........1925
Brandt, Helen Rowan, 2234 High St., Logansport...............1923
Brenton, Emily E., Worthington, 709 Atwater Ave., Bloomington..1925
Brewer, P. Harvey, 145 E. Oak St., West Lafayette.............1921
Brightly, H. S., Box 308, Bedford.............................1924
Brinton, Dr. Howard H., 403 College Ave., Richmond.............1926
Briscoe, H. J., Dept. Chemistry, Indiana Univ., Bloomington........1925
Brock, James E., Sweetser......................................1922
Brosey, Chas. L., 4034 Carrollton Ave., Indianapolis..............1922
Brossmann, Charles, 1009 Chamber of Commerce Bldg., Indianapolis 1909
Brown, Howard Dexter, Agric. Exp. Sta. Purdue Univ., Lafayette.1924
Brown, Oliver W., 526 N. Washington St., Bloomington..........1925
Brown, Pearl J., Edgewood, Apt. 7, Terre Haute.................1924
Brown, Roy E., 421 S. Fourth St., W. Lafayette..................1926
Bryan, Kenneth V., 220 Waldron St., West Lafayette...........1924

Burmaster, Rosa M., 219½ S. Jefferson, Muncie..................1926
Burton, Everett T., Bell Tel. Lab., 463 West St., New York City....1920
Burtsfield, Frank A., 813 N. Main St., West Lafayette..........1924
Bushnell, Thomas M., Purdue Ag. Exp. Sta., Lafayette..........1922
Bybee, Halbert P., 210 S. Madison St., San Angelo, Texas........1912
Byers, Cecil W., Box 332 University Station, Grand Forks, N. D..1919
Byers, Edward A., Biol. Dept., Ball Teachers College, Muncie.......1924
Cain, Stanley A., Butler College, Indianapolis....................1921
Calles, Charles D., Greentown..................................1925
Campbell, William Guy, Hanover................................1924
Campbell, M. Samuel, 29 N. Hawthorne Lane, Indianapolis........1921
Canis, Edward N., Route A-2, Box 372A, Indianapolis...........1909
Carmella, Sister, St. Mary of the Woods......................1925
Carpenter, F. F., Thorntown....................................1926
Carrick, C. W., Purdue Exp. Station, Lafayette.................1924
Carter, Annice, Ball Teachers' College, Muncie...................1926
Carter, DeVere, 314 N. Washington St., Bloomington............1925
Carter, Edgar B., 4555 Central Ave., Indianapolis................1918
Carter, Fred H., 179 Yonge St., Toronto, Canada.................1925
Cartwright, William Bell, 600 Twenty-six St., Sacramento, Cal....1925
Cassady, Emil V., 18 E. 37th St., No. 16, Indianapolis...........1920
Cavins, Alexander, Hartford Hospital, Hartford, Connecticut......1920
Chansler, Elias J., 44 N. 23rd St., Lafayette, Ind...............1895
Champion, C. C., 1205 N. 4th St., Terre Haute...................1926
Chapman, Edgar K., 506 S. Grant St., Crawfordsville...........1911
Child, Alfred T., 2305 N. 10th, Terre Haute......................1925
Childs, Mrs. Laura Goff, 921 Atwater Ave., Bloomington.........1924
Childs, Lewis, West Baden.......................................1926
Christie, George Irving, 607 University St., W. Lafayette..........1923
Church, Josiah M., 502 S. Washington St., Bloomington..........1925
Church, Wilbur O., 1028 N. 8th St., Herre Haute................1925
Clark, Jediah H., 126 E. 4th St., Connersville...................1919
Clay, Mrs. Celia, 320 N. State St., Kendallville.................1922
Clearwater, J. E., Crawfordsville..............................1925
Cleveland, Clarence R., 422 Dodge St., West Lafayette...........1921
Clowes, G. H. A., Eli Lilly & Co., Indianapolis.................1920
Coffel, Hal Herbert, Penville.....................................1923
Coleman, Christopher B., 334 State House, Indianapolis...........1925
Combs, Ruth E., 2336 Channing Way, Berkeley, Cal..............1924
Conner, S. D., 204 South 9th St., Lafayette.....................1912
Conover, James F., 2220 North 7th Street, Terre Haute..........1925
Cook, Rolla V., Bethany, West Virginia.........................1921
Coolman Raymond, 112 W. Jefferson St., Crawfordsville.........1924
Cooper, Delmer C., 27 N. Salisbury St., W. Lafayette............1926
Cooprider, J. L., Central High School, Evansville................1926
Copeland, Joseph J., Earlham College, Richmond..................1926
Coryell, Noble H., Dept. Geol., Columbia Univ., New York City....1914
Cowles, Henry C., Dept. of Botany, Univ. of Chicago, Chicago, Ill..1926
Cox, C. F., 528 N. Oxford St., Indianapolis.....................1922

Cramer, Paul, 216 Russell, W. Lafayette	1926
Culbertson, John A., Shortridge High School, Indianapolis	1924
Cullinan, Frank P., Purdue University, Lafayette	1924
Cummins, John A., 4251 Bowman Ave., Indianapolis	1923
Curtis, Lila C., 809 East 10th St., Bloomington	1920
Danglade, Ernest, Vevay	1920
Davis, Edna E., 101 Fairfield Ave., Brookville	1923
Davis, Harold Thayer, 712 E. Second St., Bloomington	1923
Davis, Luther D., 225 University, W. Lafayette	1925
Davis, Ward B., Boyce Thompson Institute, Yonkers, New York	1921
Dean, John C., University Club, Indianapolis	1914
Demaree, Delzie, Dept. Botany, Univ. of Ark., Fayetteville, Ark	1920
Deppe, C. A., Franklin, Ind	1911
Derby, Ira Harris, 3949 N. Capitol Ave., Indianapolis	1920
DeVries, Dr. Thomas, 139 S Grant St., W. Lafayette	1926
Dickens, Karl LaVon, 105 Quincy St., West Lafayette	1924
Dietz, Emil, 334 Congress Ave., Indianapolis	1921
Diggs, John, 2909 N. Talbott St., Indianapolis	1920
Dilts, Charles D., 3121 Fairfield Ave., Ft. Wayne	1920
Doan, Martha, Baher Lab. Cornell Univ., Ithaca, N. Y	1896
Doan, Richard L., Reed College, Portland, Oregon	1922
Dolan, Joseph P., Syracuse	1895
Donaghy, Fred, Biology Dept., I. S. N. S., Terre Haute	1925
Donahue, Joseph N., Columbia University, Portland, Oregon	1920
Douglass, Benjamin W., Trevlac	1916
Downhour, Elizabeth, 725 N. Pennsylvania St., Indianapolis	1915
Dugan, Elizabeth, 325 North Holmes Ave., Indianapolis	1922
Dunham, David H., 429 Main St., West Lafayette	1920
Dutton, Carl Evans, 2021 Nelson St., Fort Wayne	1924
Earp, Samuel E., 634 Occidental Bldg., Indianapolis	1909
East, Mrs. Pearl W., Gilman, Iowa	1920
Eaton, Durward L., Indiana Central College, Indianapolis	1922
Eaton, Harold S., 823 E. 12th St., Muncie	1926
Edington, William Edmund, 633 Russell St., West Lafayette	1924
Edmondson, Clarence E., 618 Ballantine Road, Bloomington	1912
Eigenmann, Mrs. C. H., 630 Atwater Ave., Bloomington	1925
Eisehard, Mrs. George B., Culver Mil. Acad., Culver	1921
Elkin, Sarah K., 612 Harvey Ave., West Lafayette	1921
Eliott, Edward Charles, Purdue University, Lafayette	1923
Elliott, Merril E., 643 Barbour Ave., Terre Haute	1924
Elliott, Seth Earl, 5852 Julian Ave., Indianapolis	1924
Emerson, Dr. Chas. P., 602 Hume-Mansur Bldg., Indianapolis	1915
Emerson, John D., 14 Andrew Place, W. Lafayette	1925
Esarey, Ralph E., 523 E. Smith St., Bloomington	1923
Esten, Sidney Raymond, 301 S. East St., Pendleton	1924
Etter, Austin, 41 Zeno St., S. W., Grand Rapids, Mich	1920
Evans, Richard I., 1133 Fulton St., Ft. Wayne	1924
Evans, Samuel G., 1452 Upper Second St., Evansville	1891
Ewbank, Roy, Kingman	1924

Ewers, James E., 1220 North 9th Street, Terre Haute.............1925
Fadley, Leon D., Sulphur Springs..............................1923
Feldman, Horace W., Bussey Institution, Forest Hills, Boston, Mass.1920
Ferguson, Luther S., Williams.................................1920
Fillingham Judith, Butler College Residence, Indianapolis........1926
Finley, George W., 18 E. National Ave., Brazil..................1923
Finster, Ethel B., 1409 Granger Ave., Ann Arbor, Mich...........1923
Fischer, George W., 5637 N. Pennsylvania St., Indianapolis........1926
Fish, William E., 106 Hunt Ave., Hillsboro, Ill.................1926
Flemion, Florence Dorothy, Dept. Genetics, Carnegie Inst., Cold Spring Harbor, Long Island, N. Y.........................1923
Fletcher, Worth A., Modoc, Indiana............................1926
Foresman, George K., 110 South 9th St., Lafayette................1914
Fowke, Gerard, Box 283, Madison..............................1924
Frazier, Jesse M., Sulphur Springs.............................1923
Frey, Franklin E., 227 S. Ritter Ave., Indianapolis...............1923
Froning, Henry B., 415 Pokagon Street, South Bend..............1920
Fugate, Mary, R. R. 1, Carmel..................................1920
Funk, Dr. Austin, 404 Spring St., Jeffersonville.................1895
Gage, George R., 112 Bloomington St., Greencastle................1923
Galloway, Jesse J., Geology Dept., Columbia Univ., N. Y. City....1910
Gamble, Mary Edith, 120 Chauncey Ave., West Lafayette..........1923
Gantz, Richard A., Indiana State Normal School, Muncie.........1920
Gardner, Raymond E., 2021 S. 7th St., Terre Haute................1925
Garner, Murvel R., Earlham College, Richmond...................1925
Garrard, Herbert Leland, 221 Waldron St., West Lafayette........1923
Garregies, John Paul, Brazil....................................1926
Garver, Frederick R., Fairland..................................1921
Gatch, Dr. Willis D., 605 Hume-Mansur Bldg., Indianapolis........1915
Gates, Florence A., 3435 Detroit Ave., Toledo, Ohio...............1909
Gayler, Dona G., 200 N. 6th St., Terre Haute....................1920
Geisler, Florence E., 2267 N. Dearborn St., Indianapolis..........1925
Geller, John W., 432 North 6th St., Terre Haute..................1925
George, Roscoe Henry, 332 W. Thornell St., West Lafayette........1924
Germann, F. A. O., Valparaiso..................................1926
Gibbons, Robert C., 140 Pierce St., W. Lafayette..................1926
Gingery, Walter G., Shortridge High School, Indianapolis..........1918
Giordano, Dr. Alfred S., Epworth Hospital, South Bend...........1926
Glenn, Earl Rouse, 425 West 123d Street, New York City..........1909
Goldsmith, William M., Southwestern College, Winfield, Kansas....1914
Gorhorn, Benjamin V., 117 S. Alabama, Brazil...................1926
Gracy, Dr. Alice, 1222 Twenty-fifth St., South Bend..............1926
Graham, Frank V., Indiana State Normal, Muncie.................1920
Graves, Benjamin H., 754 Orange St., New Haven, Conn...........1920
Green, Darrell R., R. R. No. 1, Martinsville, Ill...................1925
Greenawalt, Stewart, Madison, Pennsylvania.....................1924
Greene, Frank C., 1434 Cincinnati Ave., Tulsa, Oklahoma.........1908
Greene, Laurenz, 920 Seventh St., West Lafayette...............1924
Gregory, Charles T., 1022 First Street, West Lafayette...........1922

Gregory, Howard Wilbur, 416 Harvey Ave., West Lafayette.......1924
Grosjean, Thomas H., 1312 Center St., Terre Haute..............1925
Guernsey, E. Y., 1420 O Street, Bedford........................1921
Guthrie, William A., 10 E. Market St., Indianapolis..............1920
Hadley, Joel W., 4445 Guilford Ave., Indianapolis................1919
Hagey, George Lee, 543 S. Eddy Street, South Bend.............1920
Hammond, Alyce L., 51 Glendale Park, Hammond................1923
Hanna, U. S., 828 Atwater Ave., Bloomington..................1914
Hansford, Hazel I., Southeastern Hosp. of Insane, North Madison..1916
Hardin, Leo J., 150 N. Grant St., West Lafayette................1924
Harding, Wilbur T., 244 Littleton St., West Lafayette............1923
Hardy, Eugene H., 351 N. East St., Indianapolis................1920
Harger, Dr. Rolla Neil, 3913 Kenwood Ave., Indianapolis..........1923
Hargitt, Thomas F., Illinois Wesleyan University, Bloomington, Ill..1923
Hargrave, Elis, 818 N. Drexel St., Indianapolis..................1923
Harmon, Daniel L., St. Mary of the Woods......................1925
Harmon Paul M., 1648 Mass. Ave., Cambridge, Mass.............1915
Harshbarger, Claude H., Roachdale............................1924
Harvin, Glenn Beckham, 244 Littleton St., West Lafayette........1923
Hassenzahl, Elizabeth, 424 Vine St., West Lafayette.............1921
Hawkins, Stacy O., Edinburg..................................1924
Hayner, Clark Ross, 453 Littleton St., West Lafayette...........1923
Hazard, Clifton T., 344 N. W. Ave., W. Lafayette.................1926
Hazel, Herbert C., 1000 S. Lincoln St., Bloomington..............1925
Headlee, W. Hugh, Morristown.................................1926
Heath, Dwight Frederick, 700 E. Jefferson St., Franklin...........1924
Heck, Joseph E., 447 Vine St., W. Lafayette....................1926
Hedebol, Frederick C. N., 16 Norwood Ave., Schenectady, N. Y....1920
Heimlich, Louis Frederick, Valparaiso Univ., Valparaiso...........1914
Hendricks, Jesse C., 50 W. Julian St., Franklin..................1924
Hendricks, Victor K., 401 W. Lombard Ave., Oak Park, Ill.........1900
Hennel, Cora B., 822 Atwater Ave., Bloomington.................1925
Hepburn, Wm. Murray, 118 Waldron St., W. Lafayette............1924
Hershman, J. Bernard, 305 Monroe, Valparaiso...................1926
Hiatt, Lee Aatta, 233 E. Arch St., Portland......................1926
Higgins, Frank R., 1719 N. 9th St., Terre Haute.................1925
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Hill, William J., 322 Kirkwood Ave., Bloomington..............1923
Hills, Donald C., 625 Udell St., Indianapolis....................1922
Hinman, Jack J., Box 313, Iowa City, Iowa.....................1912
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Hoffman, G. L., 216 Jenkins Arcade, Pittsburgh, Penn.............1911
Hoffman, Ira C., 443 Vine St., West Lafayette..................1924
Hole, Alen D., 615 National Road, West Richmond................1901
Holl, Carl Waldo, N. Manchester.............................1926
Hooper, Florence, 3411 N. Capitol Ave., Indianapolis.............1924
Howell, L. B., Wabash College, Crawfordsville...................1924

Howick, Harry, Ind. State Normal School, Muncie...............1921
Howlett, Berton A., Physics Dept., I. U., Bloomington.............1919
Huber, Leonard L., Hanover College, Hanover..................1915
Huebotter, Harry A., 326 Fowler Ave., West Lafayette...........1924
Hufferd, Ralph W., Greencastle.................................1920
Hufford, Francis G., 965 River St., Batavia, Ill.................1924
Hufford, Gayle N., 523 Hunter Ave., Joliet, Ill..................1926
Hughes, Florence, 2914 Broadway, Indianapolis.................1924
Hunt, Raymond S., 508 East 3rd St., Bloomington...............1923
Hunter, Allan Richmond, 611 S. Brandon St., Kokomo.............1924
Hunter, Mrs. Stephen, 208 Ridge Ave., Lawrenceburg............1925
Hutchinson, Emery, Norman Station 1915
Hutton, Joseph G., State College, Brookings, South Dakota........1911
Hyatt, George F., 624 N. Ireland St., Greensburg.................1925
Hyslop, George H., 116 E. 63rd St., New York, N. Y............1914
Inskeep, Anna M., Monticello...................................1924
Irons, Vernal, Jasonville.......................................1925
Irving, Thomas P., Notre Dame University, South Bend...........1914
Jackson, Jas. Wm., Central High School, Chattanooga, Tennessee..1918
Jaleski, Thomas Clarence, 1420 East 10th St., Indianapolis.........1924
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Jensen, Howard E., 360 Downey Ave., Indianapolis..............1921
Johnson, William, 3645 N. Denny, Indianapolis.................1926
Jordan, Charles B., 409 Russel, W. Lafayette....................1924
Jordon, Ruth, 230 Harrison St., West Lafayette................1924
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Kanter, Jacob R., 724 S. Park Ave., Bloomington................1920
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Kelly, E. Lowell, R. R. No. 3, Russiaville, Ind...................1926
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King, Mary E., 661 Poplar St., Terre Haute.....................1926
Kinnet, Russell, Milroy...1923
Kinsey, Alfred C., 615 S. Park Ave., Bloomington...............1920
Kintner, Edward, 1004 East North, Manchester..................1926
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Knotts, Armanis F., Kankeetown, Fla............................1917
Kohl, Edwin J., 218 Fowler Ave., West Lafayette.................1917
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Lancaster, Forrest W., 1421 Congress St., West Lafayette........1926
Lanterman, W. F., 230 Pierce St., West Lafayette...............1925
Larrimer, W. H., Bur. of Ent. U. S. Dept. Agric., Washington, D. C.1921
Leach, William J. Fowlerton.....................................1926
Leaming, Eleanor Patton, 825 South 9th Street, W. Lafayette.....1923
Leamon, Grace, Stockwell..1924
Lee, Charles O., 208 Sylvia St., W. Lafayette.....................1926
Leer, Wayne E., 502 Waldron St., W. Lafayette...................1924
Lefler, Ralph W., R. 3, Warren..................................1926
Lieber, Richard, State House, Indianapolis......................1919
Liston, Jesse G., R. R. No. 2, Lewis............................1916
Little, Neil, 300 Sylvia St., W. Lafayette........................1926
Lockenwitz, A. E., 314 E. Baker St., Bloomington, Illinois........1925
Long, Betty, Atlanta..1926
Long, (Mrs.) Gertrude, 2111 S. Jefferson St., Muncie..............1926
Loughridge, Gasper Arthur, Fillmore, Ill.........................1923
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Ludy, Llewellyn V., 600 Russell Street, West Lafayette...........1908
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McCarty, Morris, High School, Montmorenci.......................1917
McClintock, Ralph Blackwood, R. R. 6, Bloomington................1926
McDaniels, Alice, Shadeland & 34th St., Indianapolis..............1924
McDonald, Clinton C., 424 S. Henderson St., Bloomington..........1922
McDougle, G. Marshall, 409 Alabama St., Lafayette................1924
McEachron, Karl B., 23 Waverly St., Pittsfield, Mass.............1921
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McWilliams, Thelma, 126 Lutz Ave., West Lafayette...............1923
Mackell, James F., Dept. Physics, I. S. N. S., Terre Haute........1925
Mallon, Marguerite, 249 Littleton St., W. Lafayette..............1926
Malott, Burton J., Technical High School, Indianapolis............1916
Malott, Ruth Boyd, 629 Carlisle Place, Indianapolis..............1922
Mannfield, George N., 1235 Central Ave., Indianapolis.............1922
Martin, Ersie S., 134 N. Drexel St., Indianapolis.................1922
Martin, Earl R., Dept. of Physics, Lehigh Univ., Bethlehem, Pa...1925
Martin, Frank D., 202 North St., W. Lafayette...................1926
Martin, Lawrence, 681½ Wabash St., Terre Haute.................1926
Martin, Mrs. Viva Dutton, 134 N. Drexel St., Indianapolis........1922
Marting, Dorsey P., English.....................................1926
Mason, Thomas E., 103 Waldron St., West Lafayette.............1905
Matchett, John R., 120 Quincy St., W. Lafayette..................1926
Mathias, Harry R., 1421 Castle Ave., Indianapolis................1925
Matthews, Mary L., 356 State Street, West Lafayette............1924

Maxwell, Harold, Purdue Agric. Exp. Station, Lafayette	1926
May, Ansley I., 540 Northwestern Ave., W. Lafayette	1926
Mees, C. L., Rose Polytechnic Institute, Terre Haute	1894
Megenhardt, Dennis S., Center Point	1926
Mehrlich, Ferdinand, 20 E. 18th St., Indianapolis	1924
Mellon, M. G., 120 Quincy St., W. Lafayette	1921
Merry, Jessie Bell, 650 E. 13th St., Indianapolis	1926
Meyer, A. N., 505 Calumet Ave., Valparaiso	1926
Meyer, Huston, 111 Linwood St., Indianapolis	1925
Michael, Charles LeVerne, R. R. No. 1, Russiaville	1924
Michael, Lyle Jordan, Indiana Central College, Indianapolis	1922
Michael, Curtis B., Jasonville	1926
Middleton, Robert Elgin, 328 Lutz Ave., W. Lafayette	1924
Miller, Fred A., R. R. No. 6 or Eli Lilly Co., Greenfield	1908
Miller, John W., Penn. State College, State College, Pa	1919
Miller, Virgil H., Greentown	1925
Miller, Sayers J., 1009 S. 12th St., W. Lafayette	1926
Molony, Rev. William Hayes, Notre Dame Univ., South Bend	1922
Montgomery, Basil, E. Poseyville	1922
Montgomery, H. T., 208 Dean Bldg., South Bend	1898
Moore, Gerald E., Box 2, Hanover College, Hanover	1924
Moore, John Irwin, Box 868, San Angelo, Texas	1922
Moore, John A., 114 S. Ritter Ave., Indianapolis	1926
Moore, John M., 125 Downey Ave., Indianapolis	1921
Moore, Kenneth W., 125 Downey Ave., Indianapolis	1921
Moore, Richard Bishop, 534 Hayes St., W. Lafayette	1926
Moorhead, John Gerald, 1912 Sherman St., Evanston, Ill	1922
Morgan, Frank W., 8213 Spruce St., New Orleans, Louisiana	1920
Morgan, Lawrence Onis, Anat. Dept., Cornell Univ., Ithaca, N. Y.	1923
Morgan, Will P., 4105 Otterbein Ave., Indianapolis	1920
Morris, Vlon N., Fixed Nitrogen Laboratory, Washington, D. C.	1925
Morrison, Harold, Bureau of Entomology, Washington, D. C.	1910
Morton, W. T., Ind. Cons. Gas & By Products Co., Terre Haute	1925
Mount, Harry W., 1012 Lexington Ave., Indianapolis	1923
Mozingo, Paul Payne, Franklin Food Products Co., Franklin	1924
Mulherin, Mary Grivvin, 1320 Union St., Lafayette	1924
Mullen, Lowell, Dept. Bot., State Col. of Wash., Pullman, Wash	1925
Mullendore, Naomi, Franklin	1922
Munro, George W., 202 Waldron St., West Lafayette	1917
Myers, B. D., 321 N. Washington St., Bloomington	1911
Myers, George Sprague, Box 821, Stanford Univ., Palo Alto, Cal	1925
Neff, Joseph Edgar, 132 S. Scott St., South Bend	1923
Nelson, Ralph E., 232 Littleton St., West Lafayette	1914
Nester, Henry George, 2832 N. Capitol Ave., Indianapolis	1923
Newton, Roy Frederick, 526 Hayes St., W. Lafayette	1926
Nicholson, Thomas E., 519 N. Fess Ave., Bloomington	1918
Niles, Edward H., 4450 Guilford Ave., Indianapolis	1920
Nipper, W. Ward, 348 State St., W. Lafayette	1926
Noble, Willis Bernard, Box 495, W. Lafayette	1922

Noe, Howard R., 517 Homestead Ave., Seymour....................1924
Noyes, Harry A., New Rochelle Research Lab., New Rochelle, N. Y.1916
O'Neal, Claude E., 95 Oak Hill Drive, Delaware, O................1912
Oberholser, Harry C., 2805 18th St., N. W. Washington, D. C.....1914
Oderkirk, G. C., 339 State St., W. Lafayette.....................1925
Orahood, Harold, Union Mills.....................................1914
Orton, Clayton R., State College, Pa.............................1910
Osborne, John H., 125 Monterey St., Terre Haute...............1924
Otten, Ralph Edward, Phila. General Hospital, Philadelphia, Pa..1923
Ossenberg, June Elizabeth, 139 E. Walnut St., Martinsville........1926
Painter, Henry Raymond, Box 95, W. Lafayette.....................1921
Painter, Louise, Springport 1926
Packard, C. M., Box 495, W. Lafayette.........................1926
Palmer, Chas. Mervin, Dept. Botany, Butler College, Indianapolis..1925
Parfitt, Elliott H., 318 N. Grant St., West Lafayette...............1923
Paschen, Everett Herman, Box 172, Buckley, Ill..................1924
Pearce, Joseph Robert, Willow Hill, Ill..........................1924
Pearson, Nathan E., Dept. of Zoology, Butler College, Indianapolis.1922
Peddle, John B., 2117 N. 10th St., Terre Haute..................1924
Peebles, R. W., 1013 Hartford St., Lafayette...................1924
Peffer, Harry C., 1022 Seventh St., West Lafayette.............1914
Perkins, Wendell LeRoy, Geol. Dept., I. S. N. S., Terre Haute.....1925
Petry, Edward J., 716 Scott St., Conway, Arkansas..............1911
Pickett, Fermen L., Station 178, Pullman, Wash.................1909
Pinkerton, Earl, Box 447, Walters, Oklahoma...................1916
Pinnick, Atha A., E. 10th St., Bloomington.......................1925
Pitkin, Dr. Edward M., Martinsville Sanatorium, Martinsville.....1922
Pittenger, Lemuel Arthur, Selma..............................1926
Pittenger, John S., 700 E. 8th St., Bloomington..................1926
Pittman, Lenard E., Fairbanks..................................1926
Poffenberger, John, 400 N. College, Muncie.....................1926
Poe, Doris J., 1726 E. Washington St., Indianapolis..............1923
Pollard, Cash B., 232 Littleton St., W. Lafayette.................1921
Poorman, Alfred Peter, 329 Russell St., W. Lafayette..............1924
Porter, Bennet A., 10 W. Sycamore St., Vincennes................1923
Porter, Charles Lymann, 484 Northwestern Ave., W. Lafayette.....1923
Post, Mrs. Ida M., 920 N. Center St., Terre Haute...............1925
Potter, Andrey A., 1012 Seventh St., W. Lafayette...............1924
Potzger, John E., 1311 Linden St., Indianapolis..................1926
Powell, Horace M., 5807 Lowell Ave., Indianapolis................1926
Prentice, Burr N., 20 Waldron St., W. Lafayette.................1915
Price, Gladys, 334 S. Dunn St., Bloomington.....................1926
Price, Otho J., 605 Grant St., Terre Haute.......................1925
Price, Walter Allen, Purdue Univ., Lafayette.....................1919
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Quick, Carl J., Zoology Dept. Indiana Univ., Bloomington........1925
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Railsback, Ora L., 1003 Sixth St., Charleston, Ill.................1924

Randolph, Therne Fitz, High School, Franklin....................1926
Rauth, Adolph W., Physics Dept. Rose Poly Inst., Terre Haute.....1925
Rawles, W. P., 415 N. Park Ave., Bloomington..................1920
Reagan, A. B., Cornfields, Ganado, Arizona.......................1902
Records, Ralph L., Edinburg....................................1920
Reed, Fredda Doris, Earlham College, Richmond..................1925
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Reed, Dr. William C., 1215 Atwater Ave., Bloomington...........1923
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Richards, Dr. & Mrs. Aute, Univ. of Oklahoma, Norman, Oklahoma.1916
Ricketts, Helen E., 3215 Olney St., Indianapolis..................1923
Richter, Arthur, Jasper 1926
Ridgway, Robert, 1030 S. Morgan St., Olney, Ill.................1920
Riecken, William E., Botany Dept., Ind. Univ., Bloomington........1923
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Roberts, Harry John, Route A., Lafayette.......................1922
Roberts, Otis S., 328 S. Grant St., West Lafayette..............1925
Roberts, Chester R., 98 N. Forsythe St., Franklin.................1919
Robertson, Floyd C., Morgantown.............................1924
Robertson, Frank S., 149 S. Water St., Franklin.................1924
Robertson, Leo Fred, Pulaski....................................1923
Robinson, Harold H., 222 E. Washington St., Greencastle..........1925
Roehm, John C., R. R. 2, White Pigeon, Mich...................1924
Rogers, Ruth Anna, Box 22, Clearfield, Penn., c/o Mrs. H. White..1923
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Rothrock, Henry Shirley, 152 Sheetz St., W. Lafayette............1926
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Schaefer, May Kolmer, 1914 Broadway, Indianapolis..............1924
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Shaw, Wm. R., 306 N. Salisbury St., W. Lafayette...............1926
Sheak, William H., 154 North 21st St., Philadelphia, Pa..........1916
Sherman, George W., 304 W. Oak St., West Lafayette.............1918
Shickel, M. Alma, 634 Walnut St., Terre Haute..................1924
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Showalter, Ralph W., c/o Eli Lilly & Co., Indianapolis...........1915
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Silvey, Oscar W., College Station, Texas.........................1909
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Smith, Mervin S., Bluffton	1924
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Spangler, Iva M., Decatur	1923
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Stanton, Joseph H., 624 Swan St., Terre Haute	1926
Stark, Mrs. Connie R., 724 N. 8th St., Terre Haute	1925
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Strong, Leon Henri, Dept. Anatomy, Indiana Univ., Bloomington	1925
Strong, Martha T., Dept. Zoology, Indiana Univ., Bloomington	1925
Sulzer, Elmer G., Madison	1918
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Tatlock, Myron W., Shortridge High School, Indianapolis	1918
Taylor, George Osborn, Carmel, R. R. 2	1922
Teder, John H., Jasper	1926
Terry, Oliver P., 215 Sheetz St., West Lafayette	1914
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Trueblood, Lesta, R. R. C., Terre Haute 1925
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Turley, Harold E., 1135 Fullerton Ave., Chicago, Ill...............1921
Turner, B. B., Indiana University School of Medicine, Indianapolis.1916
Turner, William P., 222 Lutz Ave., West Lafayette..............1908
Van Nuys, W. C., Box 34, Newcastle............................1914
Voorhees, Herbert S., 804 W. Wildwood Ave., Ft. Wayne.........1896
Voris, Ralph, Zoology Dept., Indiana University, Bloomington......1924
Wagener, Frank Caster, Pres. Rose Poly. Inst., Terre Haute......1925
Wallace, Frank N., State House, Indianapolis....................1920
Warner, Walter Allen, 119 Kinsey Ave., Mt. Auburn, Cincinnati, O.1924
Warren, Harris G., Box 43, Mountain Home, Idaho...............1926
Watson, Ivan Dale, Russiaville..................................1923
Weber, Russell G., Zoology Dept., Butler College, Indianapolis......1925
Webster, Lewis, Terre Haute....................................1913
Wedl, Arthur, Leoti, Kansas....................................1924
Welch, Winona, Hotel Hoosier, Danville..........................1924
Wells, Agnes E., 420 N. Indiana Ave., Bloomington..............1924
Wenninger, Rev. Francis J., Notre Dame University, South Bend..1920
Wetherill, Richard Benridge, 525 Columbia Street, Lafayette......1924
White, A. Edward, 504 W. Wiley Ave., Bluffton..................1924
White, John, Chemistry Dept., I. S. N. S., Terre Haute..........1925
Wiancko, Alfred T., 230 South 9th St., Lafayette................1909
Wickwiser, George C., Angola 1924
Wilbur, John W., 443 Vine St., West Lafayette..................1924
Wilcox, Ralph I., Room 126 State House, Indianapolis.............1926
Wildman, Ernest A., Earlham College, Richmond..................1918
Wiley, Ralph B., 777 Russell St., W. Lafayette...................1914
Wilhite, Ida B., Butler College, Indianapolis.....................1921
Wilkins, Herbert L., 120 Quincy Street, W. Lafayette............1924
Wilkinson, Paul D., 1636 South 4th Street, Terre Haute..........1921
Williams, A. A., Valparaiso.....................................1916
Williamson, Jesse H., 411 W. Market St., Bluffton.................1921
Willis, Fred, 1920 S. 6th St., Terre Haute.......................1926
Wilson, Cyril M., 111 N. Dunn St., Bloomington..................1926
Wilson, Mrs. Etta, 9077 Clarendon Ave., Detroit, Mich............1915
Wilson, Ira T., Heidelberg College, Tiffin, Ohio..................1919
Wilson, Judson D., Zoology Dept., Indiana Univ., Bloomington.....1923
Wimmer, Merle, W. Jackson, Muncie.............................1926
Winkenhofer, Walter, Huntingburg..............................1920
Winkler, Bowlin Watt, 513 E. 2nd St., Bloomington...............1925
Wischmeyer, Carl, 201 Madison Blvd., Terre Haute...............1925

Witmer, Samuel W., 1406 S. 8th St., Goshen.....................1921
Wolfe, Harold E., 314 N. Washington St., Bloomington...........1920
Wood, Harry W., 1311 Ardmore Ave., Chicago, Ill................1912
Woodrow, Walter H., Zool. Dept., I. S. N. S., Terre Haute........1925
Woodruff, Albert E., Box C-284, Aberdeen, S. Dakota.............1921
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Wright, Emerson B., 4250 Central Ave., Indianapolis..............1926
Wright, Herman P., 506 N. Indiana Ave., Bloomington...........1925
Wynkoop, Iris Bonylin, R. R. 7, Frankfort......................1924
Young, Gilvert A., 739 Owen St., Lafayette.....................1908
Young, Herman H., Dept. Psychology, Indiana Univ., Bloomington..1922
Zebrowski, George, Villa Nova College, Villa Nova, Penn.........1920
Zehring, William A., 303 Russell St., West Lafayette............1907
Zerfas, Leon G., Thorndike Memorial Laboratory, Boston, Mass.....1921
Zetterberg, Edw., 646½ N. Elm, Muncie.........................1926
Zierer, Clifford M., Univ. of Cal., Los Angeles, Cal...............1922
Zinsser, Harvey A., Miss. St. College for Women, Columbus, Miss...1925
Zufall, Chalmers J., 2504 Main St., Lafayette...................1924
Zumstein, Reginald Bernard, 810 N. 6th St., Lafayette............1923

SUMMARY OF MEMBERSHIP

Fellows	69
Members, Active	635
Members and Fellows, Non-resident	30
Total	734

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